

ADDIS ABABA UNIVERSITY
ADDIS ABABA INSTITUTE OF TECHNOLOGY
SCHOOL OF CIVIL AND ENVIRONMENTAL ENGINEERING



**PREDICTION OF SEDIMENT YIELD TO LAKE ZIWAY RESERVIOR
AND ASSESSING REDUCTION METHODS (USING ARC-SWAT).**

MASTER OF SCIENCE IN HYDRAULIC ENGINEERING

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**A Thesis Submitted in Partial Fulfillment of Requirements for the Degree of
Master Science.**

APPROVAL

This thesis entitled with Prediction of Sediment yield to Lake Ziway Reservoir and Assessing Reduction methods using Arc-Swat (Lake Ziway, Rift valley basin, Ethiopia) has been prepared by Alemayehu Kassa /GSR/1169/11. We the members of the Examining board and Advisor approved in the partial fulfilment of the Master of Science in Hydraulic Engineering.

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CERTIFICATION

I certify that I have read and recommend for acceptance by Addis Ababa university a thesis entitled as “Prediction of Sediment yield to Lake Ziway Reservoir and Assessing Reduction methods using Arc-Swat (Lake Ziway, Rift valley basin, Ethiopia) for partial fulfilment of the requirement of Degree of master of Science in Civil Engineering/Hydraulic Engineering.

.....

Dr.Yilma Seleshi (Advisor)

Date.....

STATEMENT OF THE AUTHOR

The author declares that this thesis is not submitted to any other institution for the award of any degree. The source of all materials used in this work has been acknowledged. This thesis has been submitted in partial fulfillment of the requirements for MSc degree in Hydraulic Engineering at Addis Ababa University. Anybody can borrow it from the library obeying the rule of library.

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Signature:|.....

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September 2020.

DEDICATION

I DICTATE THIS WORK TO MY BELOVED FAMILIES

LIST OF ABBREVIATIONS

AAT	All at a Time
BMPs	Best Management practices
DEM	Digital Elevation Model
FAO	Food and Agricultural Organization/United Nations
GIS	Geographic Information System
GUI	Graphical User Interface
HRU	Hydrologic Response Units
MOW	Ministry of Water
OAT	One at a time
NSE	Nash-Sutcliffe Efficiency
NMSA	National Meteorological Service Agency
R^2	Coefficient of Determination
RS	Remote Sensing
RUSLE	Revised Universal Soil loss Equation
SUFI-2	Programme of Sequential Uncertainty Fitting
SWAT –CUP	A Computer program for calibration of SWAT model
T/ha/yr	Ton per Hectare per Year
USLE	Universal Soil Loss Equation
USGS	United States Geological Survey
UTM	Universal Transverse Mercator
WGEN	Weather Generator

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ABSTRACT

High sediment accumulation from watershed is the result of poor land use practices ,in appropriate management system and lack of suitable soil and water conservation measures .The main objective of this study is to estimate sediment yield from Lake-ziway watershed using soil and water assessment tool(SWAWT) model.

Simulation was carried out using metrological and spatial data by dividing into 11 sub basin with 116 hydrologic response units (HRUs) with calibration period (2001-2009) and validation period (2010-2012). The simulation were performed using monthly time step both for Flow and sediment data using Sequential Uncertainty Fitting(SUFI-2).With in Calibration of uncertainty program (SWAT-CUP),the model performance indicators Coefficient of Determination (R^2),Nash-Sutcliffe model efficiency(NSE) varying between 0.72-0.76,0.72-0.84 for both discharge and sediment respectively.

The simulated average annual sediment yield to Lake Ziway watershed was 2.69ton/ha/yr and the gross sediment entering to the lake was estimated to be 1.04 million ton/yr with 38.5% of deposition rate. The Spatial Variability of annual sediment yield rate is between 0.19ton/ha/yr to 6.74ton/ha/yr throughout the basin and Sub-Basin 4 and 5 were detected to be the hot spot Catchments with sediment yield value greater than 6 ton/ha/yr.

For management Scenario, Taking the existing condition of the watershed as a baseline scenario for reference purpose, three scenarios were built. The first scenario, terracing reduces Average sediment yield by 72% from 2.69 Mton/ha to 0.76Mton/ha. While filter strips reduces Average sediment yield by 42% from 2.69 Mton/ha to 1.56Mton/ha and grassed water ways by 58% from 2.69 to 1.12 Mton/ha.

Key Words: SWAT model, SUFI-2, SWAT-CUP, Sediment yield, Lake Ziway watershed

1. INTRODUCTION

1.1 Background

Ethiopia is not productive enough in Agriculture due to low fertility of the soil and temporal imbalance of the rain fall. Hence, proper utilization of the available Soil and Water resource and development of irrigation is essential to Ethiopia's agricultural development and to achieve food security (Habetamu Bewket,2017).

Poor land use practices ,in appropriate management system and lack of Suitable Soil conservation measures have played a main role in causing Erosion, land degradation and sedimentation problems in the basin.

Reservoir Sedimentation becomes a challenging problem resulting in loss of most water bodies. The graduate loss of capacity reduces the effectiveness of the life span of dams and reduces the benefits for irrigation, hydropower generation, flood control, water supply, navigation and recreation. The poor land use practices, inappropriate management systems and lack of appropriate soil conservation measures have been major causes of soil erosion and land degradation problems in the country. Ethiopia losses 1.3 billion metric tons of fertile soil due the nature of the terrain and in appropriate conservation measures (Hurni 1999)). This case needs immediate measures to save the soil and water resources degradation of the country. A river does not only convey water, but it also transports erosion products (boulders gravel, sand, silt and clay) from its catchment. If the transport capacity of the river is affected by diversion of Water from the river or by storing water in the reservoir, deposition of sediment can occur. Some depositions could be, harmful if they are not properly taken care. Change in sediment yield due to changed land use in the upstream catchments causes detrimental sedimentation.

An efficient assessment of water resources availability with great spatial and temporal resolution is essential in Ethiopia for strategic decision-making on water resource related development projects. Some adopted empirical formulas had a great uncertainty on the estimations because it does not consider complex interaction that takes place in the watershed.

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Therefore, a comprehensive understanding of hydrological processes in the watershed is a first step for successful water management and environmental restoration. Due to the spatial and temporal heterogeneity in soil properties, vegetation and land use practices, a hydrologic cycle is a complex system. Due to this we need to have mathematical model and geospatial tools to deal with the hydrological processes and hydrologic response to climate change and land use change. Hence, to analyze the sediment yield of Lake Ziway watershed with respect to quantity and quality of runoff is essential for the proper and sustainable utilization of Lake Ziway for the intended purpose. A proper investigation of the sediment and runoff yield of the catchment is essential for management of sedimentation and utilization of water resource. If these are not investigated the life of Lake Ziway reservoir is shortened by sedimentation. This thesis is intended to provide a basis for future scenario examination of water resource management of Lake Ziway catchment and also to evaluate the SWAT model capability to predict the sediment yield of Upper Lake Ziway River catchment to the Ziway reservoir.

The problem of sedimentation is a threat and devastating challenge to the existing Lake Ziway reservoir and downstream areas due to generating high runoff discharges and imposing huge sediment yield, which may result in reducing water storage capacity of the Ziway ,unless the upper watershed is treated with appropriate watershed management interventions and strategies. So it is better to focus on watershed management to reduce sediment yield and increase land cover of the area which will increase in the overall productivity of the watershed areas.

The first method of reducing reservoir sedimentation would be to reduce Sediment yield from the Basin upstream by watershed management (Mohammed, 1987). This might include afforestation, land use change and construction of micro structures to trap sediment before joining the basin. Various kinds of Land management Practices can be introduced for the degraded watershed to reduce the susceptibility of river basins in relation to sediment yield.

Basically, there are well known Best management practices (BMPs) for sediment reduction and minimizing the sediment load in the run off generated from critical source area and agricultural Activities.(Arabi et al., 2007). The effectiveness

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associated with the practice and evaluated based on the progress towards meeting the targeted amount of captured loads by applying the selected BMPs.

Different researchers have classified BMPS into different categories (e.g. Kruger *et al.*, 1997; Cunningham *et al.*, 2003; Douglas-Mankin *et al.*, 2010a; Hunik *et al.*, 2012) Structural (such as Manure storage facilities, check dams, diversion dikes, stream fencing and stabilization, terracing and alternative watering systems) vegetative and agronomic (such as cover crops, filter strips, grassed waterways, riparian buffers and reforestation), and management (such as loafing lot systems, contouring and rotational grazing) is frequently used sediment management practices.

1.2. Statement of the problem

Sediment transport leads to degraded soil productivity that causes worldwide problems such as sedimentation in many hydraulic structures basically in Reservoirs and lakes. There are many Lakes in existence today which cannot perform as designed due to filling of the storage area by sediment. Ziway basin experienced land Use and land cover change over the past decades. The basin is intensively cultivated and there is high expansion of settlement in the basin. The hydrological processes are highly related to land use and land cover change.

The Katar River showed flow variation since the hydrological processes are sensitive to land use and land cover change. The basin is undergoing due to climate change and land use change due to intensive cultivation and urbanization as a result of population growth which has an impact on hydrologic response of the basin (Tolera Kabetu, 2008).The transformation of forested land into irrigation agricultural activities and urbanization has a great influence on the land use land cover of the basin as well as on basin hydrology. Therefore, there is a need for the basin to formulate strategies to manage water resources in the basin using SWAT model to quantify the sediment yield.

Therefore, care should be given to alleviate this problem. The diagram in Figure 1.1 demonstrates the flow of cause and effect among processes of water yield and related aspects. Lakes are often threatened by loss of volume due to accumulation of sediment. Watershed, sediment and river characteristics are among the main natural causative

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factors for reduction of volume. Other important ones are reservoir size, shape, and reservoir operation strategy. Man-made activities play also a significant roles in changing the existing land pattern of the area which again changes the usefulness of the Lake.

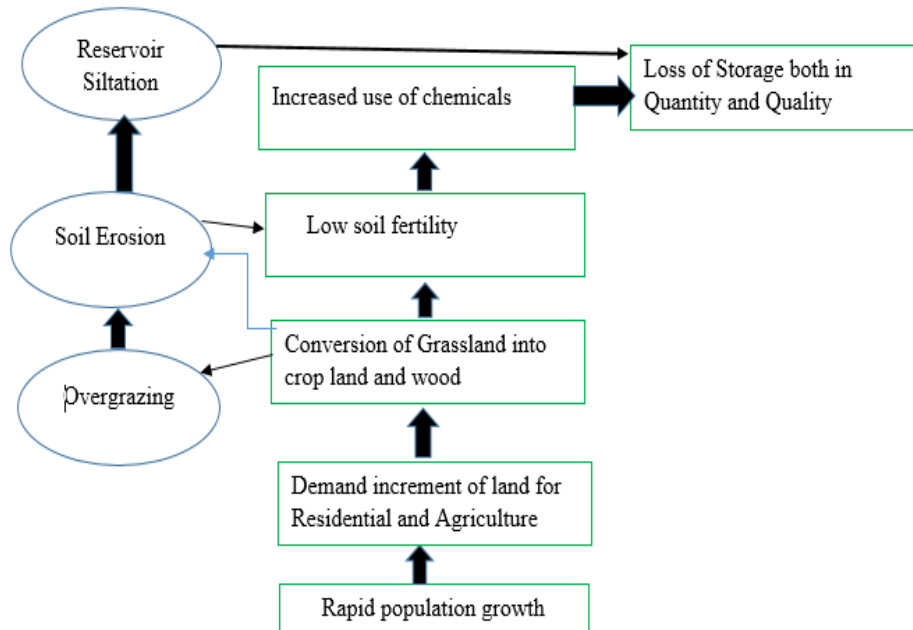


Figure 1. 1 Problem Tree

1.3. Research Questions and Hypothesis

- How much sediment yield is produced from the catchment?
- How many sediment parameters are most sensitive?
- How does land use change affect sediment yield?
- What are the appropriate measures to reduce the accumulation of sediment in the reservoir?

1.4. Objectives

The General objective of this study is to estimate sediment yield in the reservoir of Lake Ziway using ARC-SWAT software and recommend appropriate sediment reduction measures.

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1.4.1. Specific Objectives

- To estimate the sediment yield of each sub catchment.
- To identify the most erodible sub-catchment.
- Assessment of Sediment reduction methods in the catchment.

1.5 Scope of the Study

The scope of this research is limited to the estimation of catchment sediment yield using ARC- SWAT model. This study did not consider comparison of sediment yield by using another model instead of quantifying sediment yield using SWAT.

Generally, the aim of this Study is to estimate catchment sediment yield and how to reduce sediment deposition in the reservoir by using SWAT tool. It will also add a better knowledge for consideration and prediction of Sediment yield to different reservoirs providing different purpose.

Prediction of Sediment Yield to Lake Ziway Reservoir Using ARC-SWAT Software.

2. LITERATURE REVIEW

2.1 Introduction

Sedimentation caused by catchment erosion mostly reduces a significant proportion original storage capacity of many lakes (Abdallah and Stamm, 2012). Commonly, 1%-2% of reservoirs capacity lost each year due to Sediment accumulation in different parts of the world.

In order to manage sedimentation in rivers and reservoirs appropriately, there is a need to understand, define, quantify, and/or predict catchment soil erosion and sediment yield. For a river basin, the value of entering sediment can be obtained from gauge stations the sediment yield can be obtained by calculating from sediment data at gauging stations (Sadeghi and Saeidi, 2010), analyzing reservoir sedimentation data (Mhired et al., 2016); Estimating Using sediment transport Equations (Hajigholizadeh et al., 2018) and or forecasting with models (Abteu and Melesse, 2016). While, different erosion and sediment yield prediction methods are in use, no single catchment erosion and sediment yield prediction method can be presumed to be applicable to all possible conditions. All methods have limitations and advantages, and the selection of method to apply should consider a number of influencing factors, like catchment characteristics, site conditions, ecological considerations, and dam engineering requirements, availability of time, economics, data requirements, and data availability.

2.2 Soil Erosion Models

Soil loss and sedimentation by water involves the processes of detachment, transportation, and deposition of sediment by raindrop impact and flowing water (Foster and Meyer, 1977; Wischmeier and Smith, 1978; Julien, 1998). The major forces originate from raindrop impact and flowing water. Figure 2.1 shows the mechanisms of soil erosion, in which water from sheet flow areas runs together under certain conditions and

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forms small rills. The rills make small channels. When the flow is accumulated, it can cause some erosion and much material can be transported within these small channels. A few soils are very vulnerable to rill erosion. Rills gradually join together to form gradually larger channels, with the flow eventually proceeding to some established streambed. Some of this flow becomes great enough to create gullies. Soil erosion may not be noticed on exposed soil surfaces even though raindrops are eroding large quantities of sediment, but erosion can be eventual where concentrated flow creates extensive rill and gully systems.

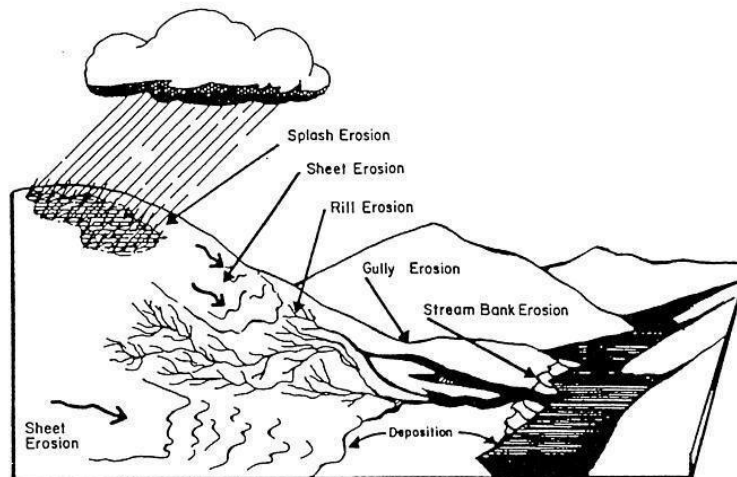


Figure2. 1 The mechanisms of soil erosion (USACE, 1985)

The Universal Soil Loss Equation (USLE) model was suggested first based on the concept of the separation and transport of particles from rainfall by Wischmeier and Smith (1965) in order to calculate the amount of soil erosion in agricultural areas. The equation was modified in 1978. It is the most widely used and accepted empirical soil erosion model developed for sheet and rill erosion based on a large set of experimental data from agricultural plots. The USLE has been enhanced many times by researchers for the last 30 years. The MUSLE, RUSLE Areal Nonpoint Source Watershed Environmental Resources Simulation (ANSWERS) (Beasley, 1989) are 1996) are based on the USLE and represent an improvement of the former. In 1996, when the U.S. Department of Agriculture (USDA) developed a method for calculating the amount of soil erosion under soil conditions besides pilot sites such as pastures or

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forests, RUSLE was announced to add many factors such as the amendment of the weather factor, the development of the soil erosion factor depending on seasonal changes, the development of a different calculation method to calculate the cover vegetation factor, and the revision of the length and gradient of slope.

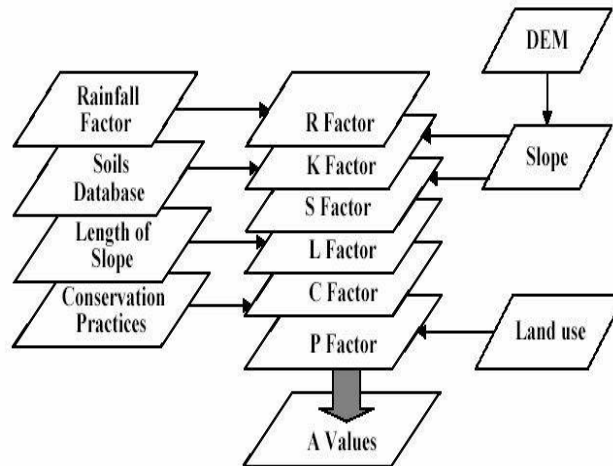


Figure2. 2 Procedures of RUSLE implementation in GIS (Nina Kemal, 2016)

The use of the USLE and its derivatives is limited to the estimation of gross erosion, and lacks the capability to compute deposition along hill slopes, depressions, valleys or in channels.

2.3 Hydrological Models

2.3.1 Types of Hydrological Models

I. Lumped models: Parameters of Lumped hydrologic model do not vary spatially within the basin and thus basin response is evaluated only at the outlet, without explicitly accounting for the response of individual sub basins.

II.Semi-distributed models: Parameters of semi-distributed (simplified distributed) models are partly permitted to vary in space by dividing the basin into a number of smaller sub-basins. There are two main types of semi-distributed models: 1) kinematic wave theory models (KW models, such as HEC-HMS), and 2) probability distributed models (PD models, such as TOPMODEL). The KW models are simplified versions of the surface and/or subsurface flow equations of physically based hydrologic models

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(Beven, 2000). In the PD models spatial resolution is accounted for by using probability distributions of input parameters across the basin.

III. Distributed models: Parameters of distributed Models are fully allowed to vary in space at a resolution usually selected by the user. Distributed modeling approach tries to incorporate data concerning the spatial distribution of parameter variations together with computational algorithms to evaluate the influence of this distribution on simulated precipitation-runoff behavior.

2.3.2 SWAT Development and Interface

SWAT (Arnold et al. 1998) is a semi-distributed, time continuous watershed simulator operating on a daily time step. SWAT is semi-physically based and allows simulation of a high level of spatial variability by dividing the watershed into sub watersheds.

The model is developed to predict the impact of land management practices on water, sediment, and agricultural chemical yields in complex catchments with varying soils, land use and management conditions over long period of time.

SWAT uses Hydrologic response Units (HRUs) to describe spatial heterogeneity in terms of Land cover, Soil type and slope within a Catchment. Hydrologic response units are sub classifications of the sub basins existed in the catchment. These units have similar features of soil, land use and slope nature.

2.3.3 Theoretical Description of SWAT

The large scale variability of the study area is represented by dividing the watershed in to Sub-basins. Each sub basin is further discretized into a series of Hydrologic response units (HRUs), which have unique Soil, land use and Slope combinations. Soil water content, surface runoff, nutrient cycles, sediment yield, crop growth and management practices are simulated for each HRU and then combined for the sub basin by a weighted average.

Physical characteristics, Such as slope, reach dimensions and climatic data are considered for each sub basin. For climate, SWAT uses data from Stations nearest to the centric of each sub basin .Channel routing is simulated using the variable storage or Muskingum method.

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The water in each HRU in SWAT is stored in four storage volumes: shallow soil profile (0-2m), snow shallow aquifer (typically 2-20m), and deep aquifer. Surface runoff from daily rainfall is estimated using a modified SCS curve number method, which estimates the amount of runoff based on local land use, soil type, and antecedent moisture condition. Peak runoff predictions are based on modification of the Rational Formula (Chow et al., 1988). The watershed concentration time is estimated using Manning's formula, considering both overland and channel flow.

Daily average soil temperature is simulated as a function of both maximum and minimum air temperature. If the temperature in a specific layer reaches less than or equal to 0° c, no percolation is allowed from that layer. Lateral sub-surface flow in the soil profile is calculated simultaneously with percolation.

The Model Computes evaporation from soils and plants separately. Potential Evapotranspiration can be modeled with the Penman Monteith, Priestley–Taylor or Hargreaves methods, depending on data availability. Potential soil water evaporation is estimated as a function of potential ET and leaf area index (area of plant leaves relative to the soil surface area). Actual soil evaporation is estimated by using exponential functions of soil depth and water content. Water evaporation is simulated as a Linear function of potential ET, leaf area index, and root depth, and can be limited by soil water content.

Sediment yield in SWAT is estimated with the modified soil loss equation (MUSLE) developed by Wischmeier and Smith (1978). The sediment routing model comprises of two constituents working simultaneously deposition and degradation. The deposition in the channel and flood plain from the sub-watershed to the watershed outlet is based on the sediment particle settling velocity. The settling velocity is determined using Stoke's law (Chow et al., 1988).

Hydrological Component of SWAT

Simulation of hydrology of a watershed is done in two separate components. One is the land phase of the Hydrologic cycle that controls the water movement in the land and determines the water, sediment, nutrient and pesticide amount that will be loaded into the main stream. Hydrological components simulated in the land phase of the hydrological

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Evapotranspiration, the value less dependent on Soil storage and more dependent on Antecedent climate.

$$S = S_{max} \left(1 - \frac{SW}{(sw + \exp(w1 - w2 * SW))} \right) \dots \dots \dots 4$$

Where S is the retention parameter for a given day (mm), S_{max} is the maximum value othe retention parameter can achieve on any given day (mm),SW is the soil water content of the entire profile excluding the amount of water held in profile at wilting point (mm)and w1 and w2 are shape coefficients .The maximum retention parameter value , S_{max} is obtained by Solving Equation 6 Using CN1.

$$S_{max} = 25.4 \left(\frac{1000}{CN1} - 10 \right) \dots \dots \dots 5$$

When the retention parameter varies with plant, the following Equation is used to update the retention parameter at the end of every day

$$S = S_{per} + E_o * \exp\left(\frac{-cncoef - S_{perv}}{S_{max}}\right) - R_{day} - Q_{surf} \dots \dots \dots 6$$

Where S is the retention parameter for a given day (mm) S_{perv} is the retention parameter for the pervious day(mm).E_o is potential Evapotranspiration for the day (mm per day),cncoef is the weighting coefficient used to calculate retention coefficient for daily curve number Calculations dependent on plant Evapotranspiration S_{max}, is the maximum Value the retention parameter can achieve on any given day (mm).R_{day} is the rainfall depth for the day (mm) and Q_{surf} is surface run off (mm).The intial value of the retention parameter is defined as S=0.9*S_{max}.

The SCS curve number is a function of the soil permeability, land use and antecedent soil water condition. SCS defines three antecedent moisture conditions: I dry (wilting point), II average moisture and III wet (field Capacity). The moisture condition I curve number is the lowest value the daily curve number can assume in dry conditions. The curve number for moisture conditions III and I are calculated with equations 8 and 7 respectively.

$$CN1 = CN2 - \frac{20 * (100 - CN2)}{(100 - Cn2 + \exp(2.533 - 0.0636 * (100 - CN2))} \dots \dots \dots 7$$

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$$CN3 = CN2 * \exp(0.00673 * (100 - CN2)) \dots \dots \dots 8$$

Where CN1,CN2 and CN3 are is the moisture condition in I,II,&III curve number,

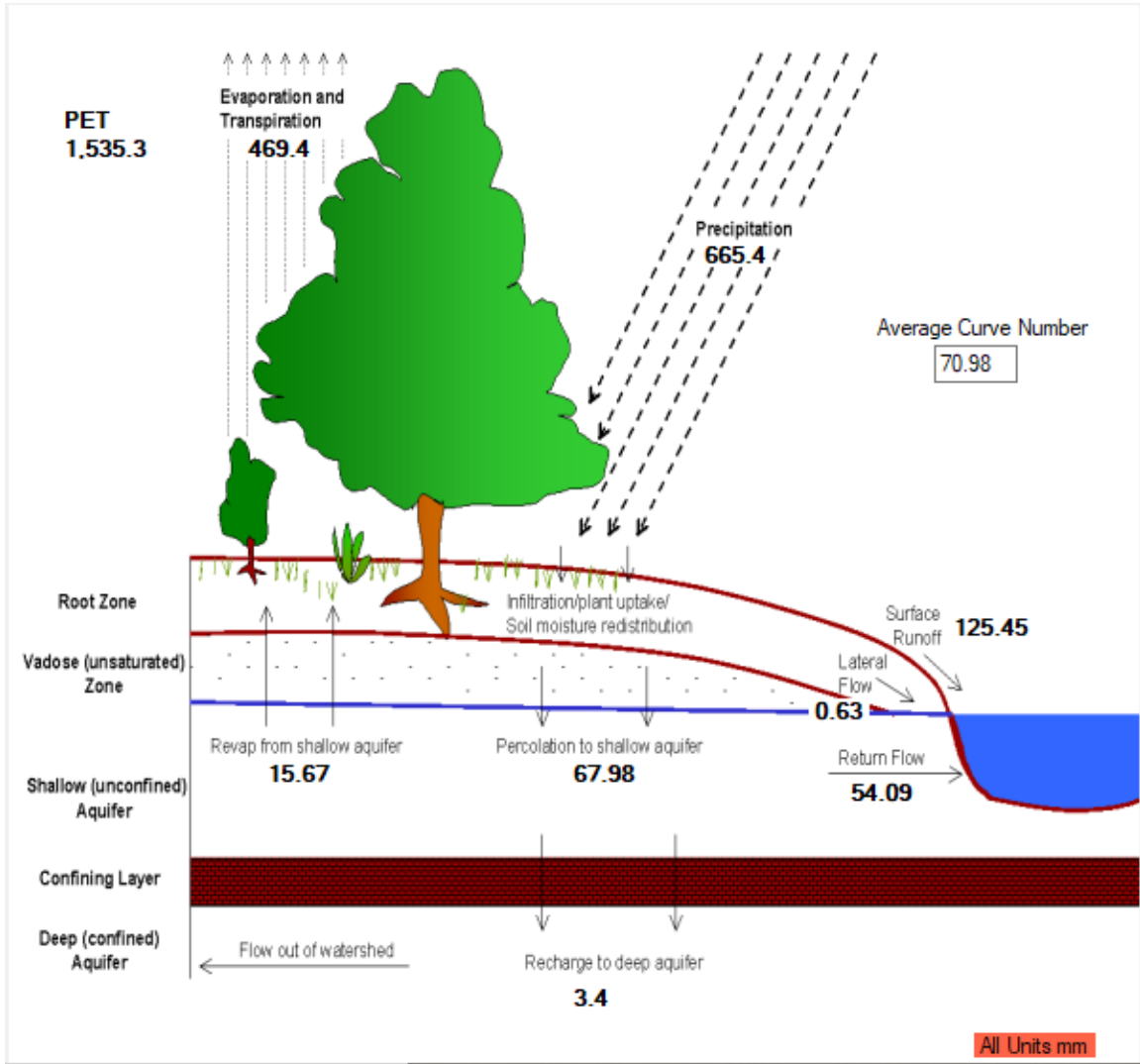


Figure 2.3 Land phase of Hydrological cycle of Lake Ziway Watershed (simulation Result).

Sediment Component of SWAT

SWAT computes erosion caused by rainfall and runoff with the Modified Universal Soil Loss Equation (MUSLE) (Williams, 1975)

$$Sed = 11.8 * (Q_{sur} Q_{peak} Area_{hu})^{0.56} K_{USLE} .C_{USLE} .P_{USLE} .L_{SUSLE} .CFGR \dots \dots \dots \text{Equ2.2}$$

Where Sed is the sediment yield on a given day (metric tons),

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Q_{surf} is the surface runoff volume(mm/ha) ,

q_{peak} is the peak runoff rate (m³/s),

$Area_{hru}$ is the area of the HRU (ha)

K_{USLE} is the USLE soil erodibility factor

C_{USLE} is the USLE cover and management factor

P_{USLE} is the USLE support practice factor

LS_{USLE} is the USLE topographic factor and $CFGR$ is the USLE coarse fragment.

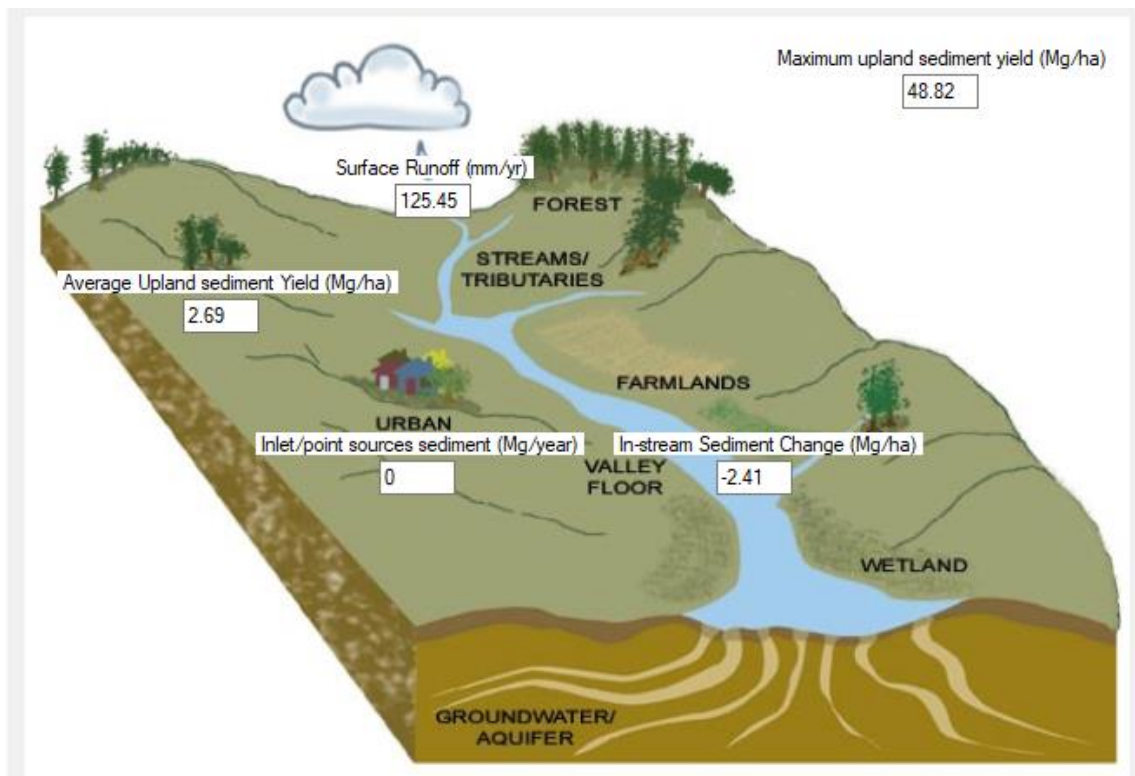


Figure2. 3 Simulated sediment of Lake Ziway Watershed (from simulation Result).

2.4 Sediment Transport Equations

Erosion caused by rainfall and runoff is computed with the Modified Universal Soil Loss Equation (MUSLE) (Williams, 1975). MUSLE is a modified version of the

Prediction of Sediment Yield to Lake Ziway Reservoir Using ARC-SWAT Software.

Universal Soil Loss Equation (USLE) developed by Wischmeier and Smith (1965, 1975). USLE predicts average annual gross erosion as a function of rainfall energy. In Modified Universal Soil Loss Equation, the rainfall energy factor is replaced with a runoff factor. This improves the sediment yield prediction, eliminates the need for delivery ratios, and allows the equation to be applied to individual storm events. Sediment yield prediction is improved because runoff is a function of antecedent moisture condition as well as rainfall energy. Delivery ratios (the sediment yield at any point along the channel divided by the source erosion above that point) are required by the USLE because the rainfall factor represents energy used in detachment only. Delivery ratios are not needed with MUSLE because the runoff factor represents energy used in detaching and transporting sediment.

2.4.1 Modified Universal Soil Loss Equation (MUSLE)

MUSLE empirically represented as follows

$$\text{Sed} = 11.8 * (Q_{\text{sur}} Q_{\text{peak}} \text{Area}_{\text{hu}})^{0.56} K_{\text{USLE}} .C_{\text{USLE}} .P_{\text{USLE}} .L_{\text{SUSLE}} .CFGR.$$

2.4.2 Surface Run-off.

Surface runoff occurs whenever the rate of water application to the ground surface exceeds the rate of infiltration. When water is initially applied to a dry soil, the application rate and infiltration rates may be similar. However, the infiltration rate will decrease as the soil becomes wetter. When the application rate is higher than the infiltration rate, surface depressions begin to fill. If the application rate continues to be higher than the infiltration rate once all surface depressions have filled, surface runoff will commence.

Surface Run -off calculation

SWAT uses two methods for surface runoff calculation: (1) SCS curve number method, and (2) Green-Ampt Method (Green and Ampt, 1911). It is reported in literature that SCS curve number performs better than Green-Ampt method (Ponce and Hawkins 1996, Kannan et al. 2006). In addition, Green-Ampt infiltration method requires hourly precipitation data, and flow routing at hourly time step which makes the model computationally demanding for long term simulations. Therefore SCS curve number method is used in this thesis. Curve Number for antecedent moisture condition

Prediction of Sediment Yield to Lake Ziway Reservoir Using ARC-SWAT Software.

II (CN2) are adjusted for sub watershed slope in the model, and these values are updated on daily time step based on soil moisture conditions in the root zone.

Runoff-Volume

The SCS run off Equation is an empirical model that came into common case in the 1950s. It was the product of more than 20 years of studies involving rainfall-runoff relationships from small rural watersheds across the U.S. The equation was established to afford a consistent basis for estimating the amounts of runoff under varying land use and soil types (Evans, BM and D.A Miller, 1988). The SCS curve number equation is (SCS, 1972):

Swat Model Selection criteria

The model used here in this Study is SWAT, Which is an interface of ARC –GIS. It was successfully used for various studies of Water resource area. it is used for analyzing the impact of land use land cover change on stream flow in many watersheds. Damtew Fufa (2015) applied to katar watershed to evaluate its simulating capacity through calibration and Validation on monthly basis and recommended to use the model for further simulation and analysis of land use/land cover change on hydrologic regime of Katar watershed for future research. Besides the model software with some tutorial video is accessible and freely available on Swat website (Soil and water Assessment Tool <http://swat.tamu.edu/>) to download.

Furthermore,

- It has the Capacity of estimating sediment yield with many input variables.
- SWAT is public domain software.
- Uses readily available inputs.
- The model is capable of simulating major watershed hydrologic processes.
- Computationally efficient to operate on large basins in reasonable time.
- The model has a community of developers and users that help each other for better understanding.

An Accuracy predictive capacity of SWAT model depends on accuracy of input data which is major problem in developing countries like Ethiopia.

Prediction of Sediment Yield to Lake Ziway Reservoir Using ARC-SWAT Software.

3. METHODS AND MATERIALS

3.1 Description of Study Area

3.1.1 Location

Lake Ziway, belongs to the Central Ethiopian Rift valley lakes basin having a total area of 7285km² and geographically it extends from 7°20'54" to 8°25'56" latitude and from 38°13'02" to 39°24'01" longitude covering almost the northern edge of Rift valley .It has a maximum length and width of 32 and 20km, respectively. It has a surface area of 423Km², maximum depth of 7.2m and average depth of 2.5m. Lake Ziway is the one of shallowest lake in the country.The Rift valley basin Lakes Basin is situated in the southern part of the country, encompassing the southern segment of the main Ethiopian Rift, stretching northeast- southwest just north from Lake Ziway via Lakes Abiyata, Langano, Shala, Hawasa, Abaya, Chamo and Chew Bahir up to the border with Kenya. The total surface area is approximately 53,000Km² and represents relatively one of the smallest basins in the country. It is bordered by the Awash River Basin in north and northeast, Omo River Basin in west, Genale Dawa River Basin and Wabi Shebelle River Basin in the east and northeast respectively and the Ethiopian Kenya border in the south.

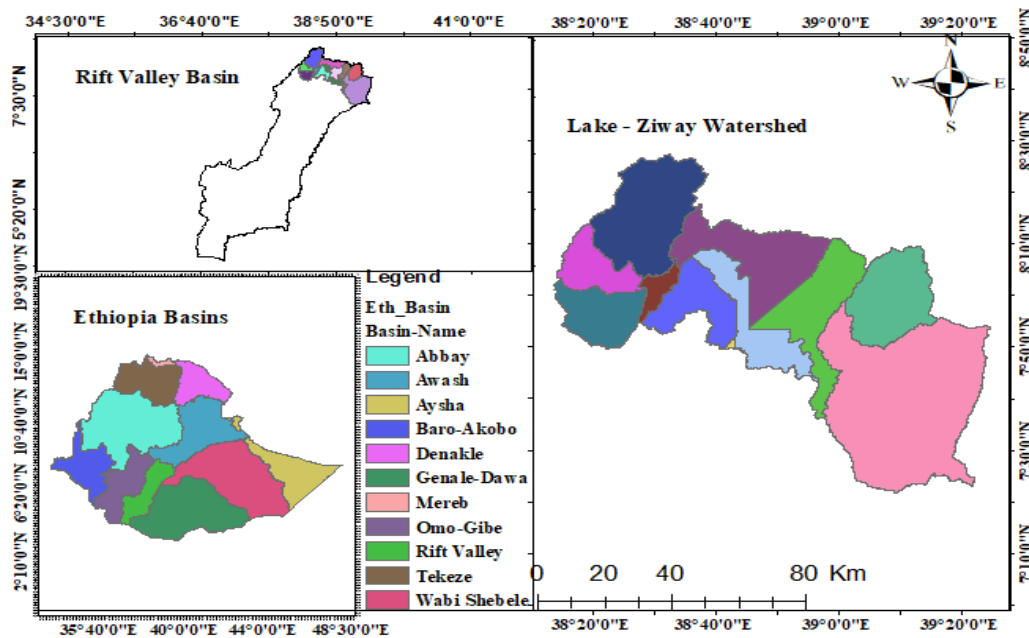


Figure3. 1 Map for location of Study Area.

Prediction of Sediment Yield to Lake Ziway Reservoir Using ARC-SWAT Software.



Figure3. 2 Map of Study Area from Google Earth.

Prediction of Sediment Yield to Lake Ziway Reservoir Using ARC-SWAT Software.

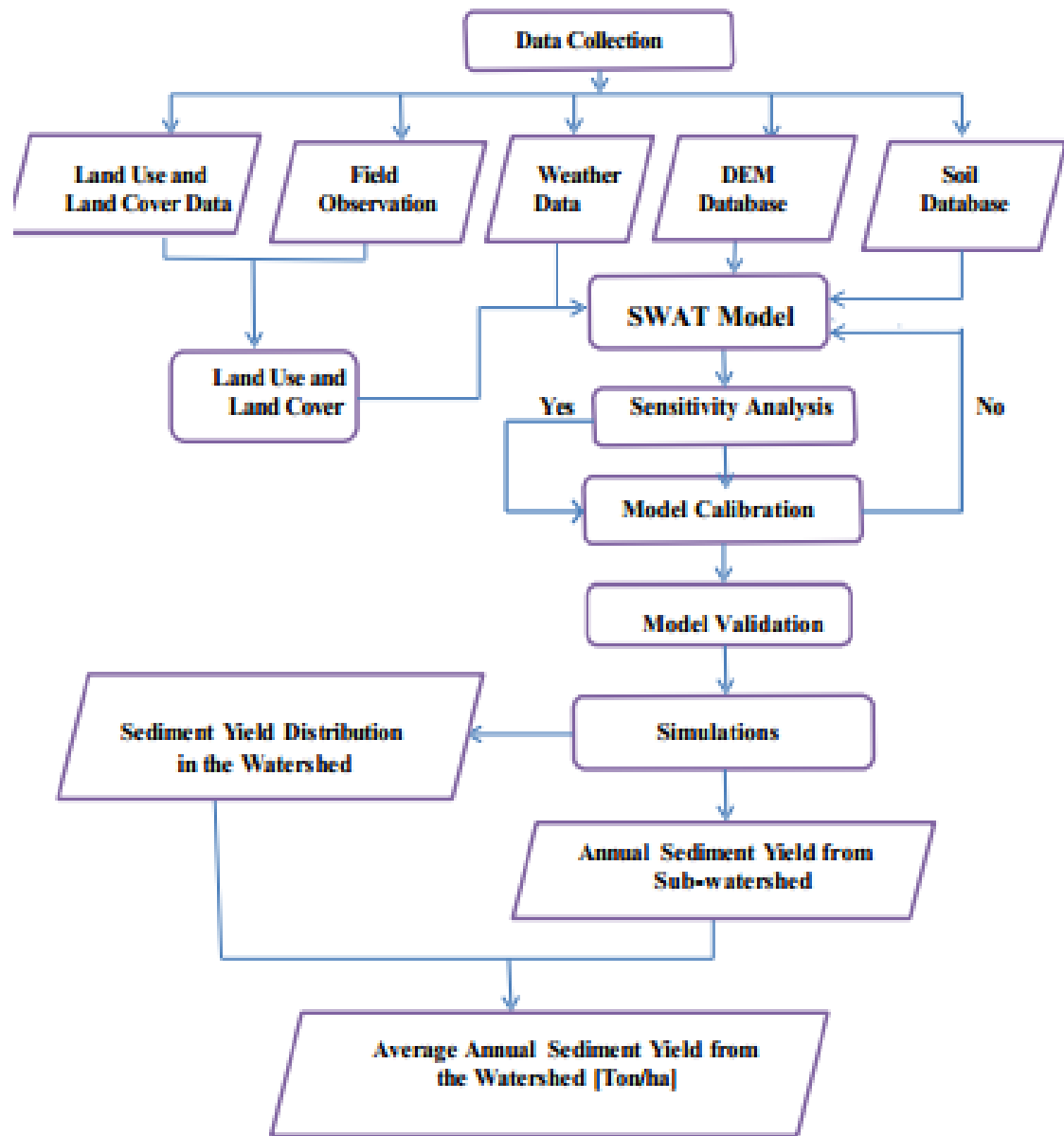


Figure3. 3 Framework of the Study.

The framework above indicates the general work flow of Ziway watershed .After identifying problem of statement ,the objective of the research was set .then various type of data such as spatial (LULC,Soil map,DEM) and hydro metrological (climate variables and stream flow) data were collected. Processing of these spatial data with Arc toolbox of GIS to Extract the DEM and LULC and clipping of the soil Map as per the boundary of the watershed have been done. Once the Spatial data have been prepared then SWAT data base created in one folder. After preparing SWAT data base watershed

Prediction of Sediment Yield to Lake Ziway Reservoir Using ARC-SWAT Software.

delineation, Hydrologic Response Unit Analysis, Write Input tables for weather stations were performed. Then the Swat model was run and the simulated values was compared with observation data. Then the manual calibration was done to adjust prior to automatic calibration .sensitivity analysis was done using SWAT-CUP. After sensitivity analysis was done and finally the calibrated model was run using the sensitivities parameters. The result had good performance value and used for Validation of the model.

3.2 Data collection

The data required for this study included Spatial (Digital Elevation Model, Land use/Land cover and Soil) data which was used to create raster layers, daily data of climatic variables (percipatation,maximum and minimum temperature, relative humidity, solar radiation wind speed) and stream flow data. The five climatic variables was used to simulate basin hydrological responses whereas stream flow data used for Calibration and validation of the model.

3.2.1 Spatial Data

DEM data

The topography any point in the watershed is described by Digital Elevation Model (DEM).The DEM Data used for delineation of watershed boundary, Stream networks and to create Sub-basins of the watershed.

For this study, the DEM of Rift valley basin 30m by 30m resolution was obtained from Ministry of Water and land resource center, Department of GIS. Ziway Watershed DEM was Extracted from the RF DEM and used in watershed delineation .It was projected to Adinndand UTM zone of 37 to create overlay with the land use raster data set and Soil using GIS 10.4 and used to generate watershed Boundary using SWAT.

Prediction of Sediment Yield to Lake Ziway Reservoir Using ARC-SWAT Software.

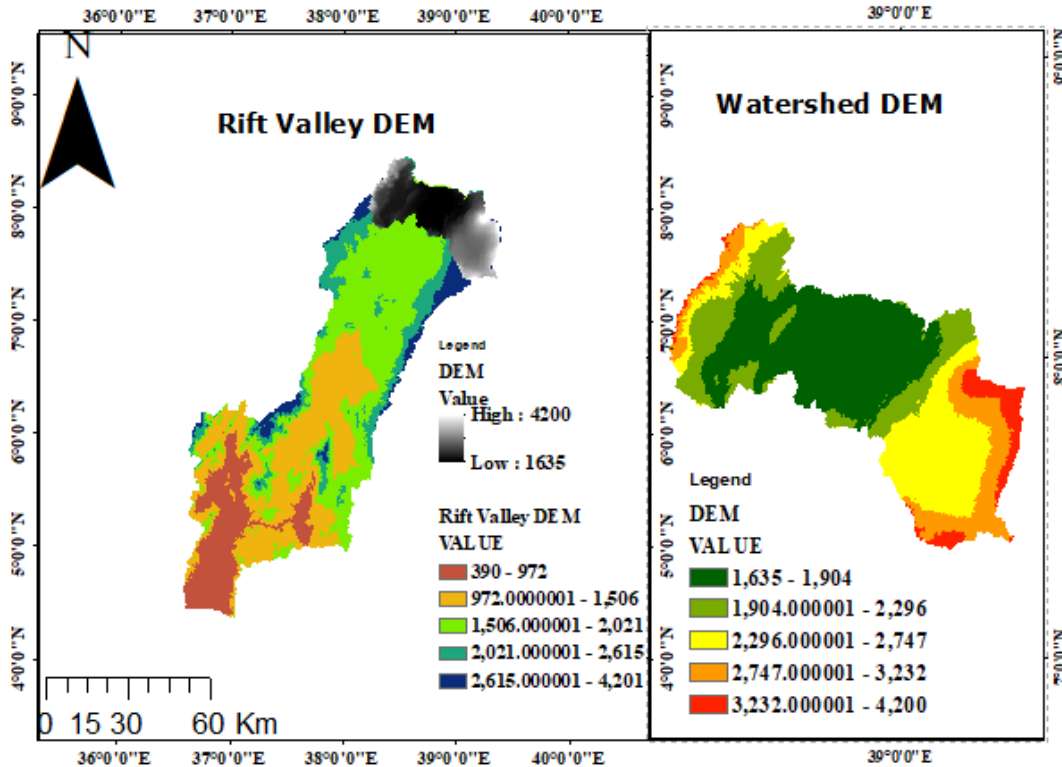


Figure 3.4 Digital Elevation model of Rift valley and Ziway Watershed.

3.2.2 Climate

According Makin M.J. et al (2005), climate of the study area consists of three ecological zones: humid to dry humid lands, dry sub-humid or semi-arid lands and semiarid or arid lands. Accordingly, highland areas west of Butajira and east of Assela are categorized under humid to dry sub-humid land. The areas east of Butajira around Lake Abiya and a strip of land between Lake Ziway and Assela are dry sub-humid lands.

The rest of the area which is around the lake is in semiarid or arid zone. The average annual rainfall of the area including stations Bekoji Adamitulu, Bui, Butajira, Meki and Ziway varies spatially from about 620mm in lowland to over 1225 mm at extreme highland areas. The mean daily temperature also varies between 15°C and 25 °C in different physiographic areas.

Prediction of Sediment Yield to Lake Ziway Reservoir Using ARC-SWAT Software.

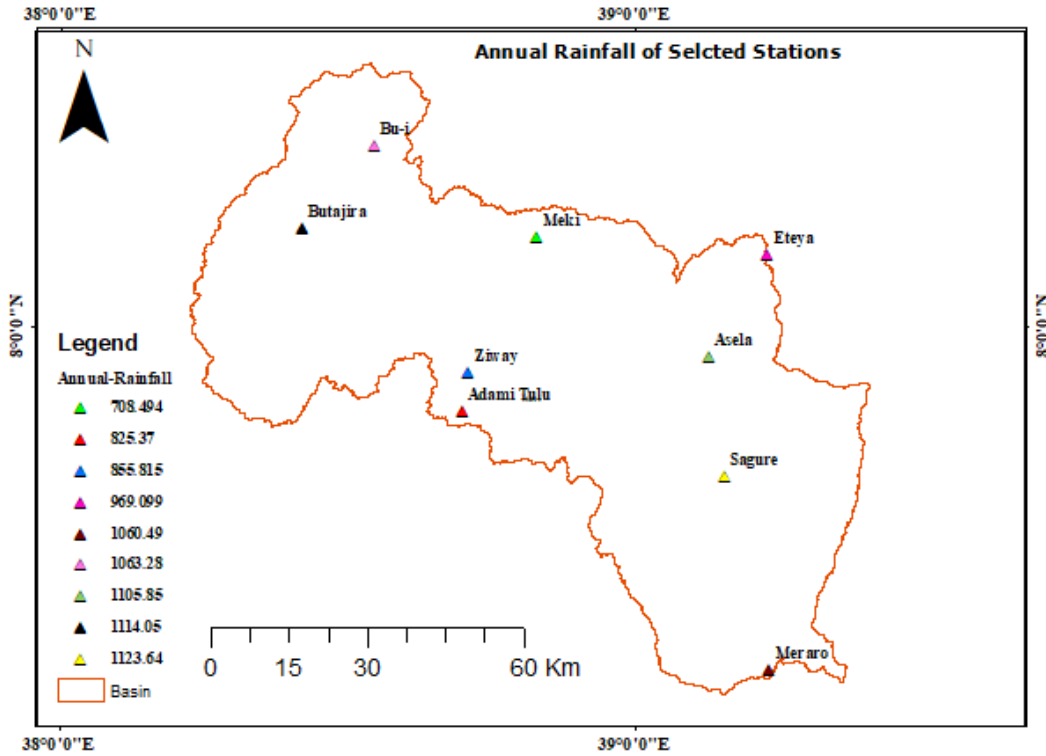


Figure 3. 5 Annual Rainfall (mm) for Selected Stations.

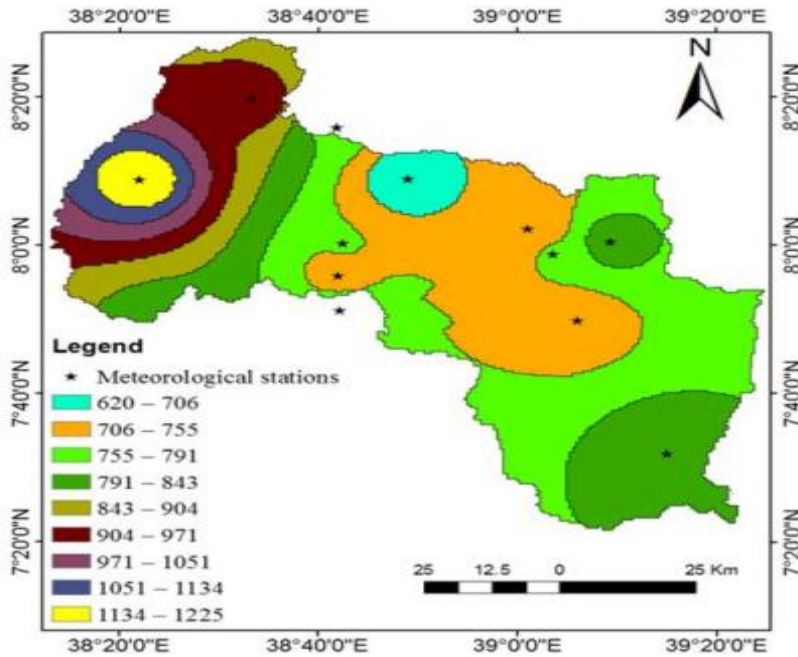


Figure3. 6 Average Annual precipitation depth using inverse distance square interpolation method in the watershed by IDW (Source:Alemu 2018).

Prediction of Sediment Yield to Lake Ziway Reservoir Using ARC-SWAT Software.

The Annual precipitation of some selected stations are shown below. In case of Adamitulu station the Rainfall were recorded to be minimum (400mm) in 2015 and recorded to be Maximum (1435mm) in 2010. While for Bui Station with the same record of years the rainfall varies from 607mm-1528mm.

The rainfall distribution in Lake Ziway watershed varies from higher altitudes in the mountainous regions to the low land areas. Figure 3.8 Shows the monthly rainfall distribution (1987-2017) of the study Area .It indicate that July, August and September are the wettest months of the year in all selected rain gauge Stations.

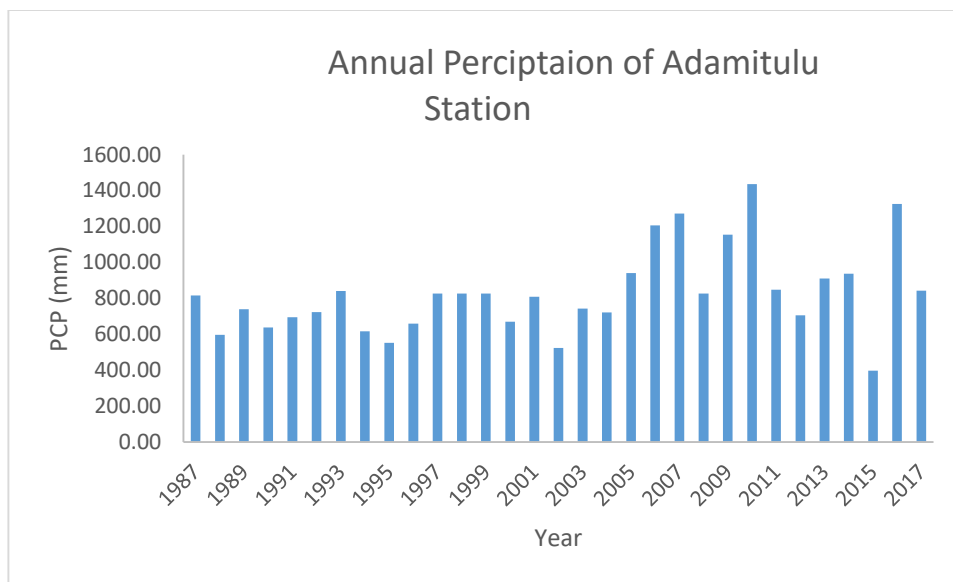


Figure3. 7 Annual Rainfall Adamitulu Station.

Prediction of Sediment Yield to Lake Ziway Reservoir Using ARC-SWAT Software.

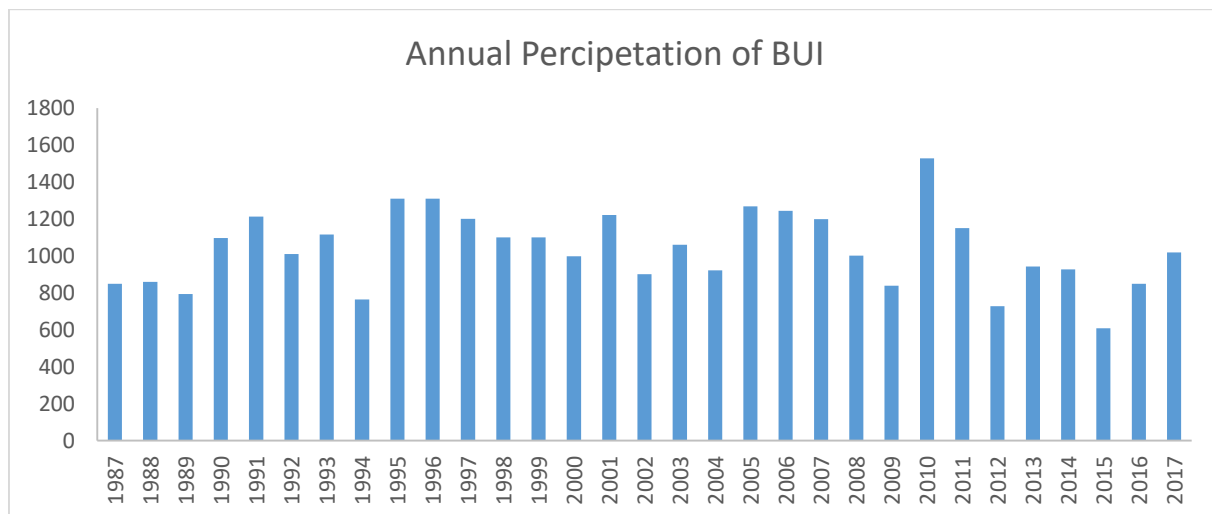


Figure3. 8 Annual Rainfall Bui Station.

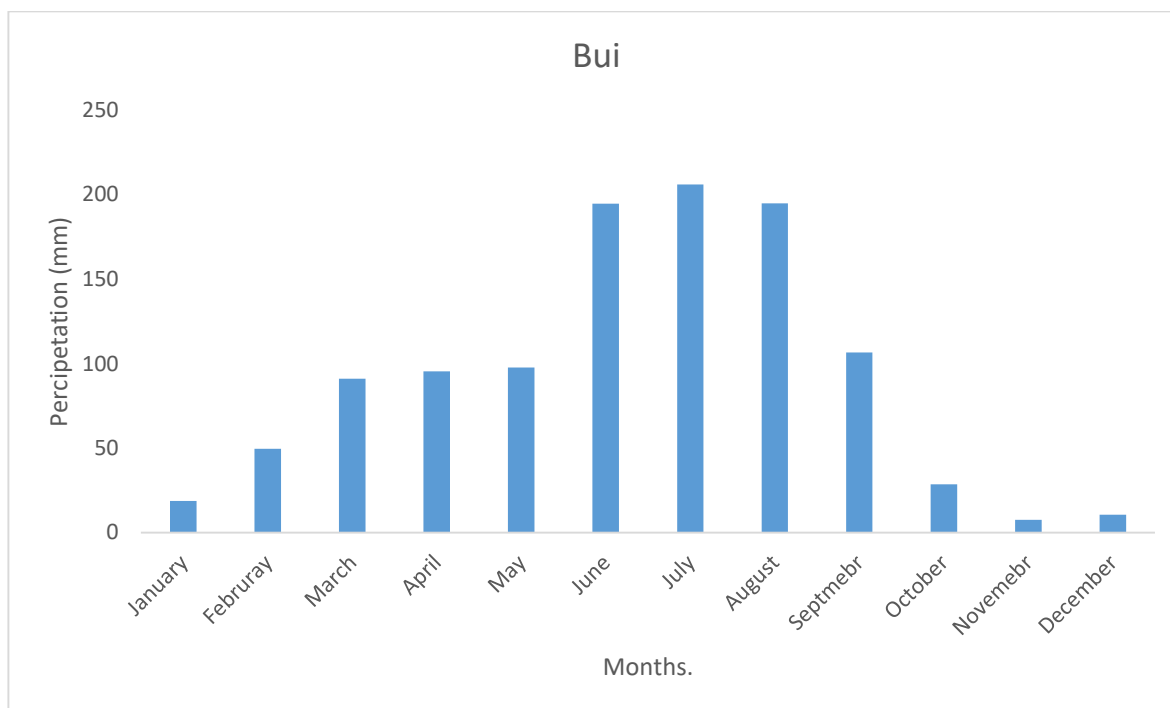


Figure3. 9 Mean Monthly rainfall of Bui Stations.

Prediction of Sediment Yield to Lake Ziway Reservoir Using ARC-SWAT Software.

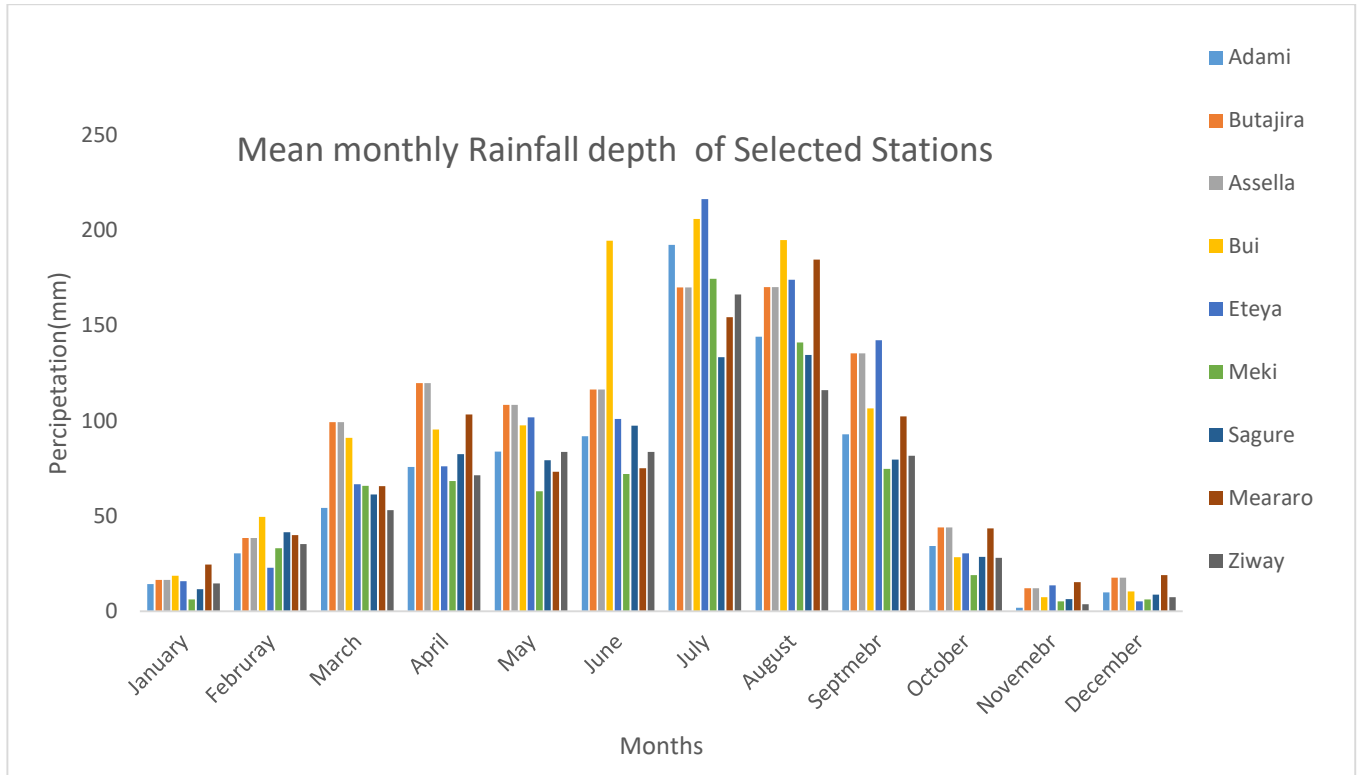


Figure3. 10 Mean monthly precipitation of selected Stations

The figure below shows the Variation of Average annual temperature from 25-27°C for maximum temperature and 6-13°C for minimum Temperature for Bui Station from 1987-2017.

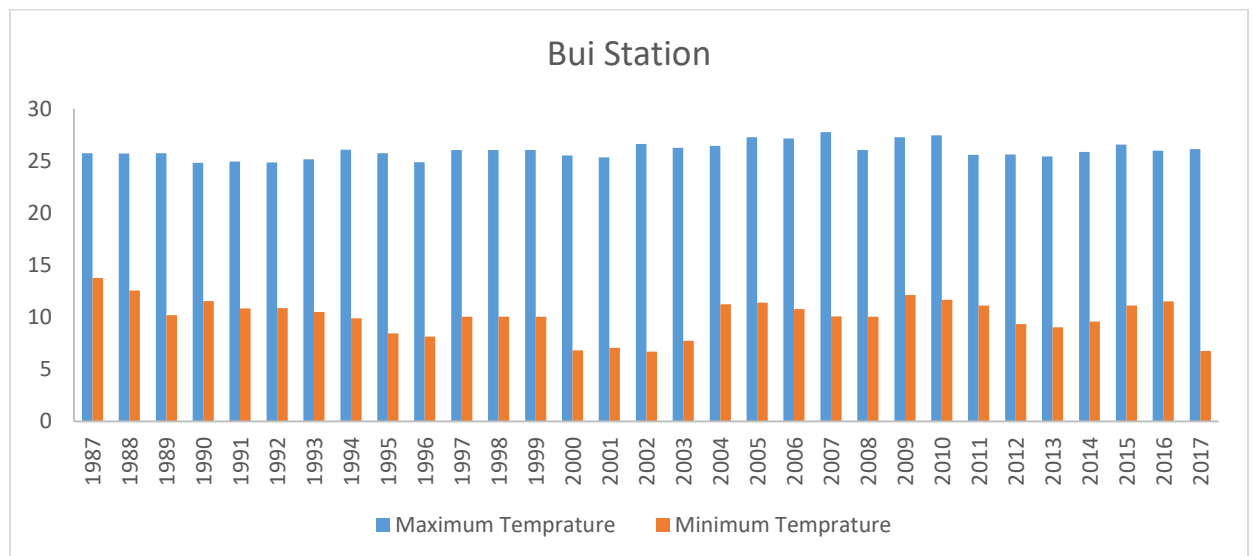


Figure3. 11 Mean Annual Maximum and Minimum Temperature (1987-2017)

Prediction of Sediment Yield to Lake Ziway Reservoir Using ARC-SWAT Software.

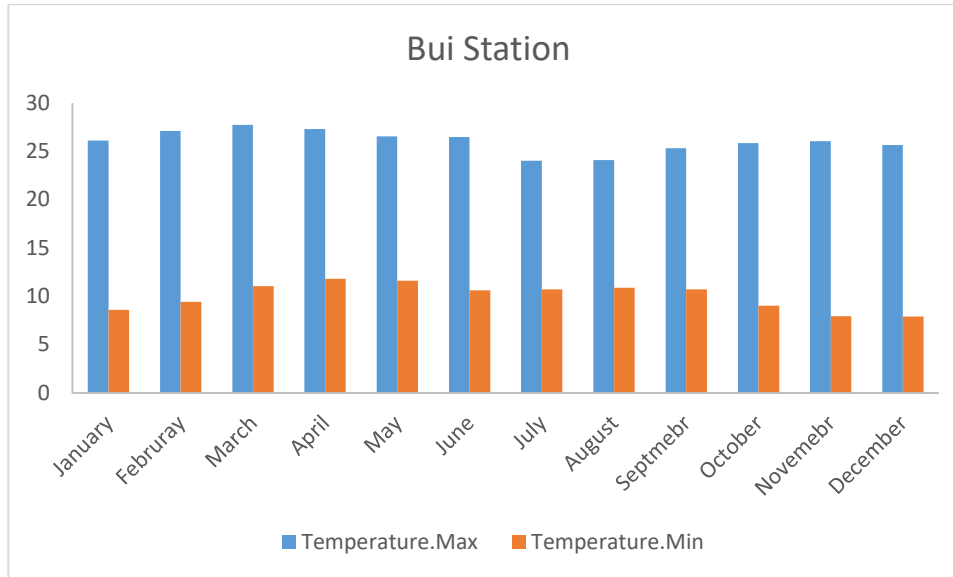


Figure 3. 12 Mean monthly maximum and minimum temperature

3.2.3 Land Use /Land Cover

Land use/land covers have a major impact on runoff generation of the watershed. Therefore, land use /land cover classification is a mandatory to assess the impact of land use/ land cover change on flow resulting in Variation of Sediment yield.

The dominant land use in the Ziway watershed is agriculture. The basin is intensively cultivated and different crops are grown in the basin using both rain and irrigation. The main crops produced in this scheme are onion, cabbage, potato, sugarcane, carrot etc. Crops like teff, maize and bean are also cultivated during the rainy season. The catchment provides water for domestic (rural and urban water supply) and agriculture sectors. Based on the Shape file Data that is obtained from ministry of Water and land Resource Center. The existing Land Use Land cover of Lake Ziway Sub basin is classified in to ten major groups as shown below in Figure 3.5. Some previous studies on Lake Ziway for different purpose classified the LU/LC in to seven or eight classes. Almost all rejects Barren Land and Shrub/bush and some others leave even the woodland type.

Agriculture: Areas in the map consisting of both cultivation areas and Agroforestry totally covering 64.22% of LU/LU in Lake- Ziway Sub basin

Forest land: Area covered with dense trees which includes mixed forest and plantation forest. This covers 11.38% of LU/LC.

Prediction of Sediment Yield to Lake Ziway Reservoir Using ARC-SWAT Software.

Wetlands: Area that is saturated with water, and either permanently or seasonally covered (waterlogged and swampy).

Barren Land: an empty land neither covered nor used for anything, too poor to grow or produce any vegetation.

Grass (Pasture) land: Areas covered with grass used for grazing and bare lands that have little grass or no grass cover.

Afro Alpine: Areas covered with vegetation on high land areas and which is green throughout the year.

Settlements: Built Up area areas of residential buildings.

Water body: Areas covered with Water, central section of the watershed containing the Lake.

Wood land: Containing wooden lands

The LU/LC map of the study area was coded to the SWAT four letter codes and linked to the SWAT land use database. Hence, after preparing the look up table the land use types were made compatible with the input required by the model.

Prediction of Sediment Yield to Lake Ziway Reservoir Using ARC-SWAT Software.

Table 3. 1 Land use/Cover Classification of Lake –Ziway Watershed.

The data was obtained from Water and Land resource center which was captured in 2016.

Land use/land cover type	Land use According to Swat Database.	Swat code
Agriculture	Agricultural Land Row Crops	AGRR
Afro-Alpine	Forest Evergreen	FRSE
Forest	Forest Mixed	FRST
Grassland	Pasture land	PAST
Wet lands	Wetlands Non Forested	WETN
Settlements	Residential High Density	URHD
Water Body	Water	WATR
Barren land	Land without vegetation	BARR
Forest	Forest deciduous	FRSD

Prediction of Sediment Yield to Lake Ziway Reservoir Using ARC-SWAT Software.

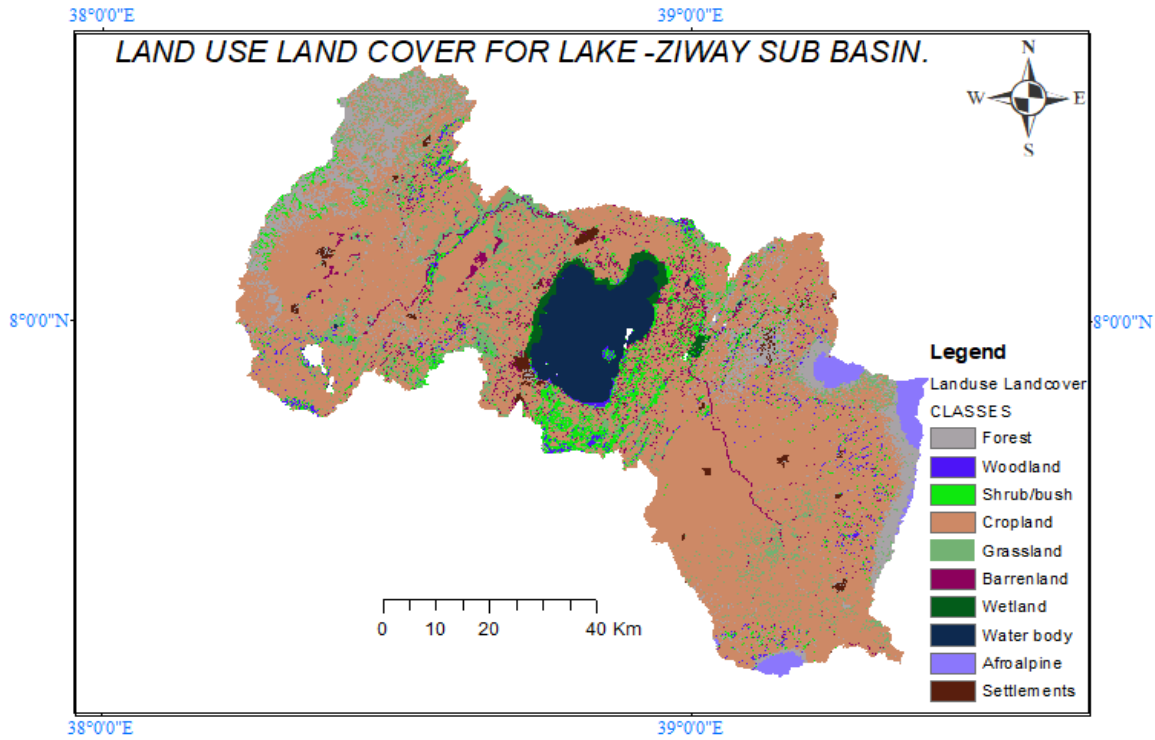


Figure3. 13 Land Use Land cover of Lake Ziway.

3.2.4 Soil

Soil data is a major and significant component in the study of sediment yield estimation hydrological components of watershed.

Table3. 2Major Soil types of Lake Ziway Basin

Soil types	Soil type description
Andosol	Deep to very deep, very dark grey to brown, medium and coarse textured, weak to moderate developed, fine and medium, crumb and sub angular blocky structure, very friable to friable; slightly sticky and none plastic, well to excessively drained.
Cambisols ,	Shallow to very deep; very dark grey to dark reddish brown; fine to coarse textured; moderate to strong developed fine to coarse, sub angular, granular and crumb structure; very friable to firm, none sticky to very sticky, none plastic to very plastic; well to excessively drained.

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Fluvisols	Moderately deep to very deep; black to dark yellowish brown; fine to coarse textured; Weak to moderate, fine and medium, granular and sub angular blocky structure; very Friable to firm, none sticky to sticky, none plastic to plastic; imperfectly to well drained
Leptosols	Very shallow; very dark grey to brown; coarse textured; weak to moderate, fine and medium sub angular blocky structure; Friable, slightly and slightly Plastic; well to excessively drain.
Luvisols	Moderately deep to very deep; very dark grey to dark; fine and medium textured; moderate to strong, granular, crumb and sub angular blocky structure; very friable to firm, slightly sticky to sticky; slightly sticky to very sticky; Moderately well to well drained.
Nitisols	Moderately deep to very deep; very dark brown to dusky red; fine and medium textured; moderate to strong, medium and coarse, sub angular blocky structure; very friable to slightly firm, sticky and plastic; well drained.
Solonetz	Deep to very deep; black to light olive brown; medium and coarse textured; moderate, medium and coarse sub angular blocky structure and massive in substrata, very friable, slightly sticky and slightly plastic; moderately well to well drained.
Vertisol	Deep to very deep; black to dark yellowish brown; fine textured, loam; moderate to strong, medium and coarse angular and sub angular blocky Structure; firm to very firm, sticky and plastic; imperfectly to poorly drained.

Prediction of Sediment Yield to Lake Ziway Reservoir Using ARC-SWAT Software.

Currently, using the data from Ministry of water and land resource center, here are the major types of soil in the watershed as shown in figure 3.14

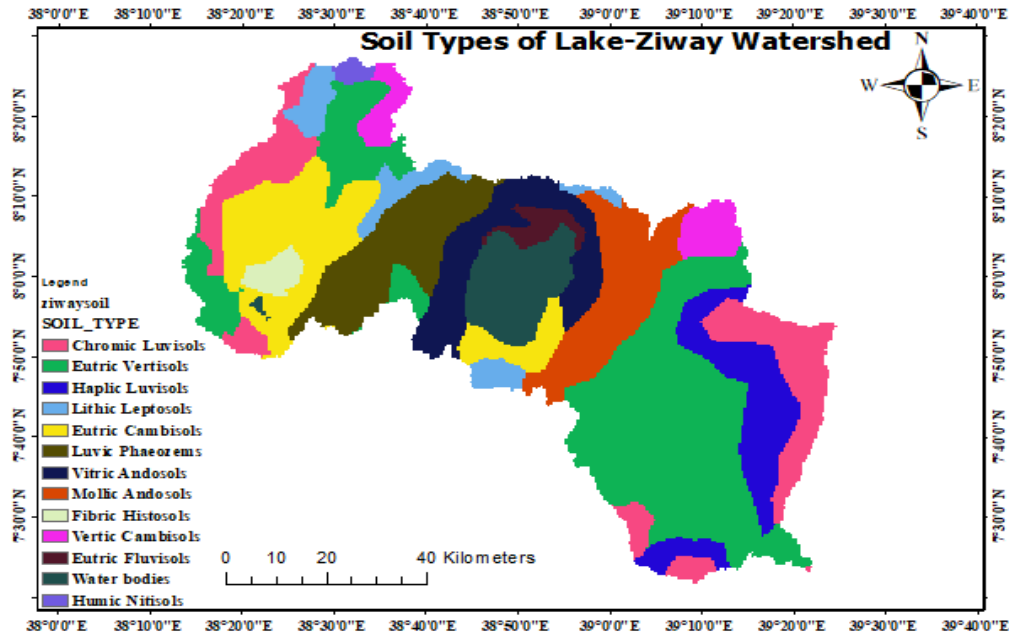


Figure3. 14 Soil types of Study Area.

3.3 Hydro Metrological Data.

Weather data are one of the major input data for Swat Simulation. The weather data includes data of daily precipitation, maximum temperature, minimum temperature, relative humidity, wind speed and solar radiation. All are obtained from Ethiopia National and metrological agency. Sixteen weather Stations were collected and only nine of them were selected based on the continuous data set and best representation of the Watershed.

The figure below Figure3.15, Shows the Stations used for Lake Ziway watershed for this Study which are Adamitulu, Bui,Meki ,Butajira,Merarao,Ziway,Assella,Eteya and Sagure. The climate data used for this study covers from 1987-2017.Except Some Stations among the nine stations almost all have the five basic variables needed for Swat input. All Weather data were vertically prepared on excel using Excel INDEX and Swat

Prediction of Sediment Yield to Lake Ziway Reservoir Using ARC-SWAT Software.

Weather Database generator finally saved it in notepad (.txt) and on Excel (.csv) format with lookup table as required by the SWAT model. Then using Swat Weather Database generator, the Excel (.Csv) containing Station code, Station name, latitude, longitude and elevation have been imported. The Data base itself generates all the parameters by creating new folder containing the station location and Values of the variables. The Data base generator represents temperature, precipitation, wind speed, relative humidity and solar radiation by TEMP, PCP, WND, HMD and SLR respectively.

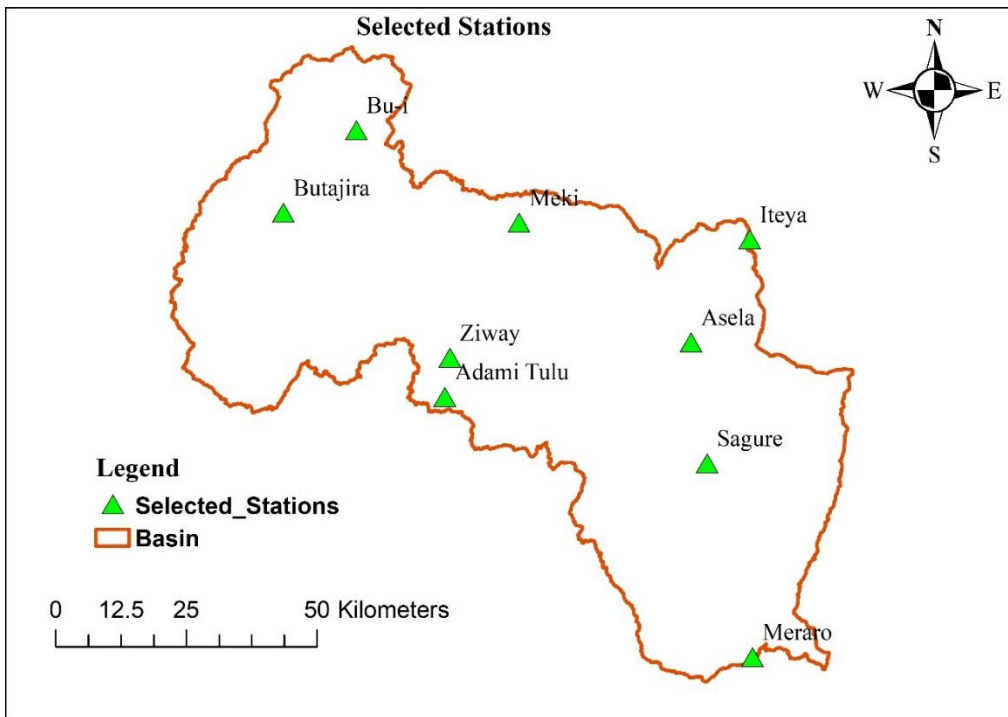


Figure3. 15 Location Map of Metrological Stations in the study Area

Table3. 3 Metrological Station Name, Locations and Variables

Prediction of Sediment Yield to Lake Ziway Reservoir Using ARC-SWAT Software.

St.Name	Year of Records	Latitude	Longitude	Elevation	Precipitation	Max. Temp	Min. Temp	Relative Humidity	Wind Speed	Solar Radiation
Adamitulu	1987-2017	467386	868398	1604.3	Yes	Yes	Yes	Yes	Yes	No
Assella	1987-2017	514126	878747	2310.9	Yes	Yes	Yes	Yes	Yes	Yes
Bui	1987-2017	449691	920146	2012.1	Yes	Yes	Yes	No	Yes	Yes
Butajira	1987-2017	436337	903787	2028.4	Yes	Yes	Yes	Yes	No	No
Etheya	1987-2017	525478	898111	2174.2	Yes	Yes	Yes	Yes	Yes	Yes
Meki	1987-2017	481742	901116	1641.5	Yes	Yes	Yes	Yes	No	Yes
Merrao	1987-2017	525144	818319	3068.1	Yes	Yes	Yes	No	Yes	No
Sagure	1987-2017	517131	856045	2454.9	Yes	Yes	Yes	Yes	No	No
Ziway	1987-2017	468054	876410	1665.5	Yes	Yes	Yes	No	Yes	Yes

Stream flow Data

For Calibration and Validation, flow data is basic and mandatory. Daily stream flow data was obtained from Ministry of Water and Electricity, department of Hydrology. Since the stream flow data had some missing data, years (2001-2012) had been chosen for continues dataset .For SWAT calibration and validation, flow data is required. According to discharge recorded at Harekelo Station (2001- 2012) average monthly flow with continuous data set is chosen.

The stream flow had missing data and no data is available for the some years. The missing and no data were excluded from calibration and validation. The calibration and validation were done on monthly basis (calibration 2003-2009 and validation 2010-2012 with warming period of the first two years (2001 and 2002).

3.4 Weather Data analysis.

In any hydrological fields of Study, it is better to have Stationary, consistent and homogenous data from different stations in the entire watershed. Thus one needs to check the quality of the hydro-meteorological data before using them to analyze and solve problems related to water resources directly or indirectly. The daily data of

Prediction of Sediment Yield to Lake Ziway Reservoir Using ARC-SWAT Software.

$$P_x = \frac{1}{N} \left(\frac{N_x}{N_A} P_A + \frac{N_x}{N_B} P_B + \frac{N_x}{N_C} P_C + \dots \dots \dots \frac{N_x}{N_n} P_N \right) \dots \dots \dots 3.2$$

Where P_x is the precipitation for the Station with missed record , $P_A, P_B, P_C, \dots, P_N$ the corresponding precipitation at the index stations and N_B, N_C, \dots, N_n are the cross ponding long- term mean monthly precipitation at index stations and at station x.

The inverse distance weighing method can be used to fill the missing data (Equation 3.3)

$$P_{x=PX} = \frac{1}{D} \left(\frac{1}{d_A^2} P_A + \frac{1}{d_B^2} P_B + \frac{1}{d_C^2} + \dots \dots \dots \frac{1}{d_N^2} P_N \right) \dots \dots \dots 3.3$$

$$\text{And } D = \frac{1}{d_A^2} + \frac{1}{d_B^2} + \frac{1}{d_C^2} + \dots \dots \dots \frac{1}{d_N^2} \dots \dots \dots 3.4$$

Where D is the distance from the index stations to a missing data point,
 d_A is the distance of each corresponding index stations from the missing data point and the other symbols carry the same meaning as defined above.

In this Study missing values in all stations were filled by Average method and Normal ratio method, using Normal ratio method (equation 3.2) when mean annual precipitation of each station is available and the magnitude differs from that of each considered precipitation stations by more than 10%.

3.4.2 Data outlier test.

Outliers:-as the name indicates these are data points that depart from the trend of the remaining data. The existence of an outlier value affect the output significantly. The detention or retention of these outliers can significantly affect the magnitude.

The data obtained from national metrological agency consisting of five basic variables have been checked using on MS-Excel precisely.

$$X_H = X_{avg} + K_N \cdot S \dots \dots \dots 3.5$$

$$X_L = X_{avg} - K_N \cdot S \dots \dots \dots 3.6$$

Where X_H and X_L are higher and lower outlier respectively

X_{avg} = mean Value of the recorded data

Prediction of Sediment Yield to Lake Ziway Reservoir Using ARC-SWAT Software.

KN=Constant value depending on sample size of the data

S=Standard deviation of the data

The principal values temperature and precipitation that will have great effect on simulated value have been checked for outlier test detail .The values beyond the higher outlier and below the lower outlier have been automatically rejected from the datasets.

3.4.3 Data homogeneity of Selected Stations.

It is important to check homogeneity since it detects the Variability of the data. When the data is homogenous, it means the data have uniformity of statistical values and the data have been measured with in the same environment by the same instrument. Sometimes meteorological data may not be homogeneous because of changes in measurement techniques and observational procedures, environment characteristics and structures, and location of stations.

Uni-modal Rainfall distribution: This are stations having one clear peak or most frequent value while Bi-modals have two clear peaks or modes.

Multi Modal: This is a distribution with more than two peaks or modes.

Among the selected nine station, four stations had Bi-modal rainfall distribution while the remaining five had Uni-Modal rainfall distribution as shown below in table.

Table3. 4 Rainfall distribution of selected stations

Stations with Uni-Modal Rainfall Distribution	Stations with Bi-modal Rainfall Distribution.
Ziway	Meraro
Meki	Sagure
Etheya	Assella
Bui	Butajira
Adamitulu	

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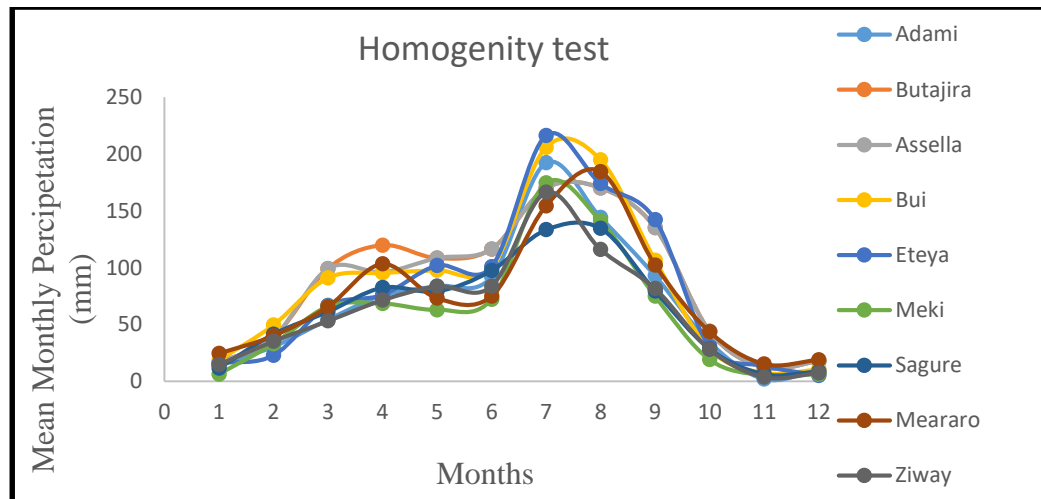


Figure 3. 16 Homogeneity test for selected stations.

3.4.4 Data consistency

The double mass curve is preferably used by hydrologists to assess the consistency of records at multiple locations, to fill gaps in records and to adjust inconsistent records (Dunne & Leopold, 1978; Giambelluca *et al*, 1986). A consistent record of meteorological data means that the statistical characteristics of the record (e.g. mean, variance, and higher-order moments) have not changed with time.

Annual precipitation amounts of each year were accumulated for each station for the period of 1987-2017. Each station's accumulated record was compared with a combined accumulated record for all the station's evaluated in Lake Ziway watershed. When we got a curves and turning points out of the normal straight lines, it reveals that rainfall data is inconsistent at that station. The data series, which is inconsistency, adjusted to consistent values by proportionality. It should be corrected by using equation 3.7

$$P_{cx} = P_x \frac{M_c}{M} \dots \dots \dots 3.7$$

Where P_{cx} is the corrected precipitation at any time period, P_x is the originally recorded precipitation at the time period, M_c is corrected slope and M is the original slope of the double mass curve.

Prediction of Sediment Yield to Lake Ziway Reservoir Using ARC-SWAT Software.

The selected stations used in this study did not undergo paramount change with in study period (1987-2017) except for Eteya and Meraro. The lines are fairly smooth with no station displaying a strong or long lasting break in slope (Figure 3.7).

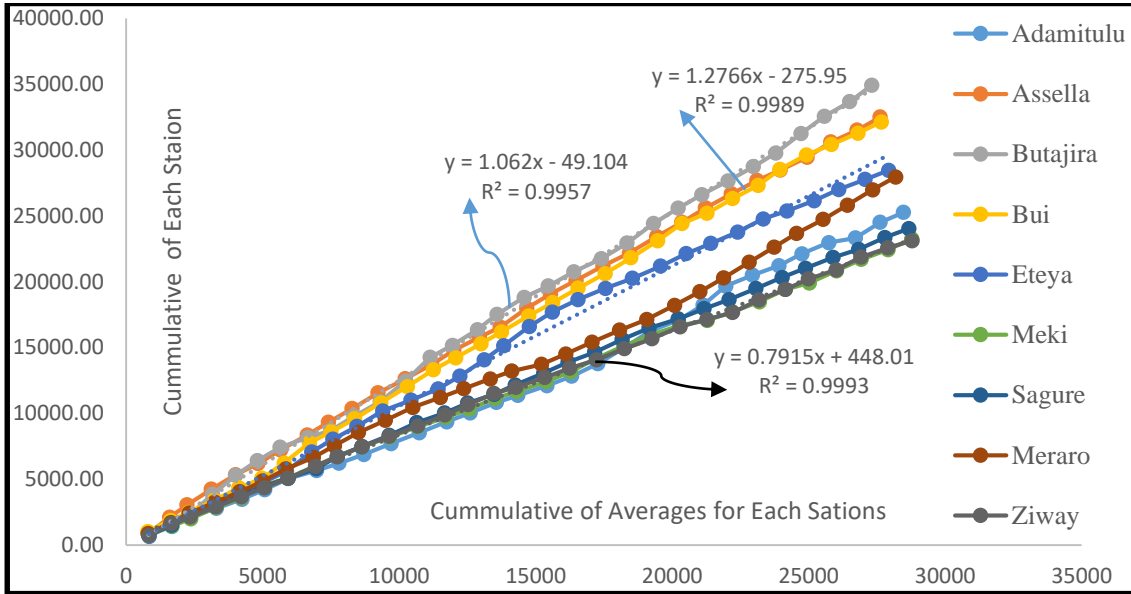


Figure3. 17 Double mass Curve (DMC) of selected stations.

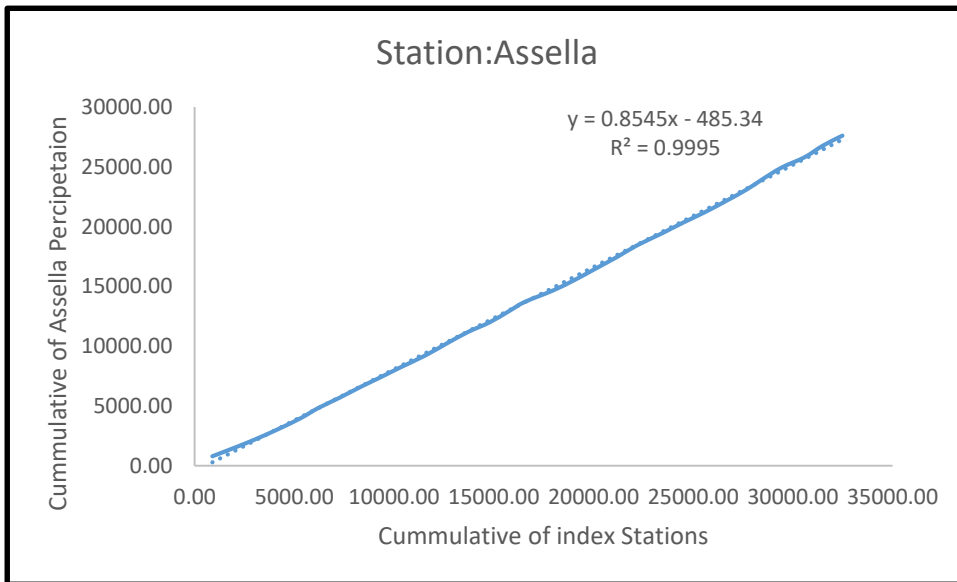


Figure3. 18 Double Mass Curve (DMC) for Assella Station.

Prediction of Sediment Yield to Lake Ziway Reservoir Using ARC-SWAT Software.

3.5 Hydrological Model Setup for SWAT.

The set up compatible with GIS version, Arc –Swat version, SWAT 2012.10.4.21 was downloaded from SWAT website (<https://swat.tamu.edu>) and it's added to GIS window from Tool bars of GIS. The model basically consists of steps from Swat project set up to SWAT simulation.

3.5.1 Watershed Delineation

The prior step next to SWAT project set up is water shed delineation. The soil Map, LU/LC map and the DEM were projected using GIS 10.4 to the same projection before the watershed delineation. This was done to overlap the three maps during SWAT modeling. The watershed and sub watershed delineation was performed using 30m by30m resolution of DEM data and using Arc SWAT model watershed delineation function. The DEM was loaded and its projection was defined. There are two options for stream definition: any user can import predefined stream network in shape file format (it can be used if the location of the streams in the catchment area is known) and DEM based (Can be used if the exact location of the streams in the catchment is not known). In this study since the exact location of the streams in the watershed were not known, the DEM based option was chosen for this Study.

Since the location of gauging station was known the outlet generated by model was modified at the gauging location for later calibration purposes. The location of the Stream flow gauging station (Bulbula, Horakelo) was manually added during the model set up process. Once the DEM set up was completed and the location of outlet was specified on the DEM, the model automatically calculates the flow direction and flow accumulation. Finally stream networks, sub watersheds and topographic parameters were calculated using the respective tools.

The stream definition and the size of sub basins were determined by selecting the threshold area or minimum drainage area required to form the origin of the streams to be thirty thousands (30000 hectares) in order to decrease sub basin number. Lake Ziway watershed was delineated into 11 sub basins having an estimated total area of 7193 km².

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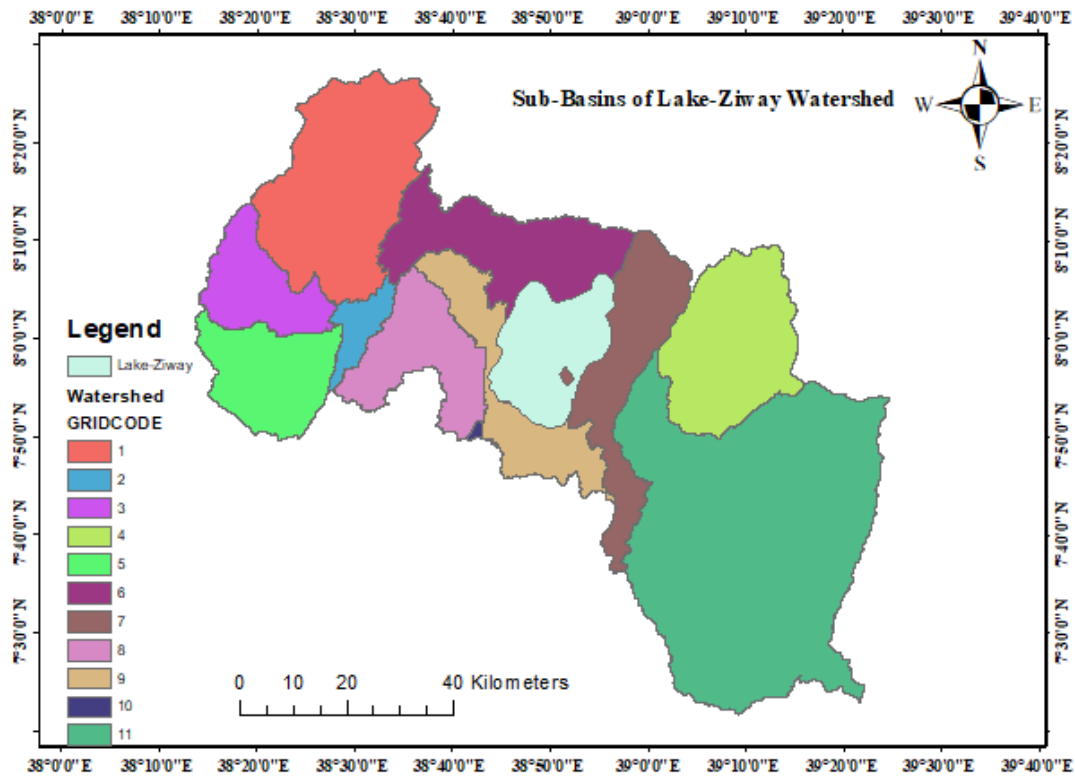


Figure3. 19 The delineated Watershed and Sub-Basins using SWAT model

Table3. 5 Coverage of Sub –basins in Lake-Ziway Watershed.

Sub-Basin	Area(Km ²)	Percentage of Area
1	947	13.16557764
2	113	1.570971778
3	328	4.559988878
4	680	9.453635479
5	425	5.908522174
6	790	10.98290004
7	688	9.56485472
8	433	6.019741415
9	476	6.617544835

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10	8	0.111219241
11	2305	32.04504379

3.5.2 Hydrological response unit Analysis (HRU analysis)

Once we accomplish watershed delineation, land use, soil and slope characterization for watershed was performed using commands from the HRU analysis menu on the Arc-SWAT Toolbar. These tools were used in loading land use and soil layers of Ziway catchment into the current project, evaluate slope characteristics and determine the land Use/soil/slope class combinations and distributions for the delineated Ziway watershed and each respective sub watershed. The watershed was divided into Hydrologic Response Unit (HRU's) which have a unique soil and land use and slope combination.

The SWAT2012 model provides three options for defining HRU distribution. The first one is assigning Dominant Land Use, Soils and Slope which form one HRU for Each sub basin. The dominant land use, soil and slope class in the sub basin are simulated in the HRU. The second is the Dominant HRU which creates one HRU for each sub basin. The dominate unique arrangements of land use, Soil and slope class in sub basin is used to simulate the HRU. And the third one is the Multiple HRUs which create multiple HRUs within each sub basin. This option was selected by Default. The SWAT user's manual recommends that a 10% soil threshold, 20% land use threshold, and 20% slope threshold are proper for most modeling application.

Therefore, for this study, HRU definition with multiple options that accounts for 10% Land use ,10% soil and 15% slope threshold combination was used to eliminate minor land use and land covers in sub basin, minor soil within a land use and land cover area and minor slope classes within a soil on specific land use and land cover area. Due to this the Ziway watershed was divided into 116 HRUs, each has a unique land use and soil Combinations.

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3.5.3 Weather Data

After HRU analysis, the weather data to be used in watershed simulation was imported using the first command in Write Input Tables menu item on the Arc- SWAT toolbar. This tool aids to load weather station locations into the current project and assign weather data. to the sub watersheds. The weather data definition is divided into six tabs containing weather generator data, rainfall data, temperature data, solar radiation data, relative humidity data and wind speed data. The data collected from the meteorological stations have a missing value.

The SWAT model requires daily hydro meteorological data from measured data or generated from values using monthly average data over a number of years. In this study data obtained from national metrology agency were used for all climatic variables. Once after filling the missing values using Normal ratio method and Arithmetic mean method, the Variables have been adjusted and prepared on MS-Excel in Three columns containing data, Station number and Parameter Value. Again Saving the values in MS-Excel (.csv) format, it have to be imported to swat weather generator database (Appendix .F).

Therefore, for weather generator data definition, the weather generator data file WGEN user, rainfall data, temperature data, relative humidity data; solar radiation data and wind speed data were selected and added to the model respectively. Once after importing the weather variables, the model could be run for the required time steps by choosing all points. In this study, SWAT run for Monthly data set with number of years to skip (NYSKIP) Appendix (H).

3.6 Model Performance Evaluation

There are no universally accepted existing standards describing the range of the values of the statistical parameters that would indicate acceptable performance of the Model (Loague,1991). But for evaluation of model performance during calibration and validation statistical measures as well as graphical representation at monthly and daily time steps were used. For this research the statistical parameters (E_{NS} and R^2) were used for model evaluation for quantification of accuracy in watershed modeling.

The coefficient of determination (R^2) describes the proportion of variance in measured data by the model. It indicates the linear correlation between simulated and observed data and ranges from zero (model is poor) to one (model is good).

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The coefficient of determination (R^2) is calculated using the Equation below.

$$R^2 = \frac{\left[\sum_i (Q_{m,i} - \bar{Q}_m)(Q_{s,i} - \bar{Q}_s) \right]^2}{\sum_i (Q_{m,i} - \bar{Q}_m)^2 \sum_i (Q_{s,i} - \bar{Q}_s)^2}$$

Where R^2 is Coefficient of determination Q is simulated variable (discharge), and m and s stand for measured and simulated.

The Nash and Sutcliffe simulation efficiency (NS) describes the derivation from the unit of the ratio of the Square of the difference in between simulated and observed data and variance of observations. The value of the coefficients varies from minus infinity to one with the latter value indicating perfect agreement between the simulated and observed data. A smaller NS value indicates poorer fit between the simulated and observed data. It is likely to obtain negative value of the NS indicating that the average of the observational data provides a better fit to the data compared to the simulated data.

Here is the formula for Calculation of Nash and Sutcliffe simulation efficiency (NSE)

$$NS = 1 - \frac{\sum_i (Q_m - Q_s)_i^2}{\sum_i (Q_{m,i} - \bar{Q}_m)^2}$$

Where NSE, is Nash and Sutcliffe simulation efficiency, Q is simulated variable (discharge), and m and s stand for measured and simulated.

4. RESULTS AND DISCUSSIONS

4.1 General

The ability of SAWT model to effectively estimate the stream flow and sediment yield was evaluated through sensitivity analysis, Model calibration and model Validation. Spatial, metrological and hydrological data played significant role to achieve the research objective by simulating Stream flow and sediment yield of Lake-Ziway watershed using SWAT model. The spatial data used during this study were digital elevation model (30m x 30m resolution DEM), land use/cover and soil map of Lake-Ziway watershed. These data were with the same scale, resolution and projection prepared and used by processing in ArcGIS 10.4 software.

The Lake-Ziway watershed Stream flow and sediment yield modeling was done by using a time series dataset from 2001 to 2012 and out of which 2001 to 2003 were used for model warm up period, 2001 to 2009 were used for calibration and 2010 to 2012 for validation period. The sensitivity analysis was done for both flow and sediment yield. The simulated flow and sediment yield were compared with the observed flow and sediment yields. Model performance was checked by statistical model performance indicators. Space-based variability of sediment yield evaluated; sediment reduction measures developed to highly sediment yielding sub basins and comparison of scenarios result was carried out.

4.2 Stream flow Simulation.

4.2.1. Sensitivity Analysis

The term sensitivity analysis refers to the identification of the most significant influencing factor in the model. Sensitivity analysis is important from two points of view: First, parameters represent processes and sensitivity analysis provides information on the basic steps of the research area. Second, sensitivity analysis helps to reduce the number of parameters by identifying the non-sensitive. Two general types of sensitivity analysis are usually performed. These are one-at-a-time (OAT) or local sensitivity analysis, and

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all-at-a-time (AAT) or global sensitivity analysis. In OAT, the effect of one parameter on the objective function is clearly dealt by keeping all remaining parameters to be constant. However, In the AAT, all parameters are changing; hence, a larger number of runs (500–1000 or more, based on total number of parameters and the steps) are needed in order to see the impact of each parameter on the objective function. Both procedures have limitations and advantages.

Therefore, prior to calibration and validation process, sensitivity was carried out to reduce the number of parameters that needs optimization.

Global Stream flow sensitivity analysis was carried out to recognize which model parameter is most sensitive in the Lake –Ziway watershed. It was done for a period of Eleven years, which includes two years warm-up period (January 1, 2001to December 31, 2003) and seven years of calibration period (January 1, 2003 to December 31, 2009).

Based on the results obtained from sensitivity analysis using SUFI-2, the ranks of parameters assigned depending on p-value and t-stat. P-value indicates significance of sensitivity and t- stat provides the measure of parameter sensitivity (Abbaspour, 2014). Regardless of the numerical sign the larger in the absolute value of t-stat means the parameter is more sensitive and p-value closer to zero means parameter has more significance effect. Thirteen parameters were used to check sensitivity analysis and the parameters that influence flow in the study area from high, medium and low were identified.

Based on the associated p-value and corresponding high t-stat values (Abbaspour, 2014) as shown below Table 4.1. In this study, Saturated hydraulic conductivity (SOL_K.sol), SCS runoff curve number (CN2.mgt), (ALPHA_BF.gw) and Available water capacity of the soil layer (SOL_AWC.sol), (SOL_BD..sol) Surface runoff lag time (SURLAG.bsn), are considered to more highly sensitive while the remaining parameters GWQMN.gw, HRU slope (HRU_SLP.hru), Channel conductivity (CH_K2.rte), EPCO.hru and ESCO.hru are medium sensitive parameters. The last three parameters were taken to be less sensitive based on t-Stat and P-Value.

Table 4. 1 Identified sensitive flow parameters rank in the Lake-Ziway watershed.

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Parameter Name	t-Stat	P-Value	Rank	Sensitivity
12:R__SOL_K(..).sol	6.563622924	0.000000124	1	High
1:R__CN2.mgt	1.993705698	0.053802798	2	High
2:V__ALPHA_BF.gw	1.279224798	0.209002014	3	High
7:R__SOL_AWC(..).sol	-1.209002577	0.234542639	4	High
9:R__SOL_BD(..).sol	0.724663185	0.473342567	5	High
8:R__SURLAG.bsn	-0.562181000	0.577476656	6	Medium
4:V__GWQMN.gw	0.506496183	0.615596528	7	Medium
6:R__HRU_SLP.hru	-0.353669091	0.725649804	8	Medium
10:R__CH_K2.rte	-0.262830863	0.794179330	9	Medium
11:R__EPCO.hru	-0.238303166	0.812997226	10	Medium
5:R__ESCO.hru	-0.119096691	0.905860873	11	Low
13:R__GW_REVAP.gw	-0.051543889	0.959177078	12	Low
3:V__GW_DELAY.gw	0.017491851	0.986140821	13	Low

4.2.2. Stream flow calibration and validation.

Calibration

The main purpose of calibration process is to know the gap between the simulated and observed value by adjusting the sensitive flow parameters in the recommended range. The nine more influential flow parameters from high to medium sensitivity and which were used for further iterations in the calibration periods are show in Table 4.2

The performance value of the model threshold depth of water in shallow aquifer for return flow to occur was good having R^2 of (0.74) and E_{NS} of 0.70 at Harekelo gauging station at outlet of watershed.

Table 4. 2 Summary of most sensitive calibrated flow parameters.

Parameter Name	t-Stat	P-Value	Rank	Sensitivity
12:R__SOL_K(..).sol	6.563622924	0.000000124	1	High
1:R__CN2.mgt	1.993705698	0.053802798	2	High
2:V__ALPHA_BF.gw	1.279224798	0.209002014	3	High
7:R__SOL_AWC(..).sol	-1.209002577	0.234542639	4	High
9:R__SOL_BD(..).sol	0.724663185	0.473342567	5	High
8:R__SURLAG.bsn	-0.562181000	0.577476656	6	Medium
4:V__GWQMN.gw	0.506496183	0.615596528	7	Medium
6:R__HRU_SLP.hru	-0.353669091	0.725649804	8	Medium
10:R__CH_K2.rte	-0.262830863	0.794179330	9	Medium

Prediction of Sediment Yield to Lake Ziway Reservoir Using ARC-SWAT Software.

11:R__EPCO.hru	-0.238303166	0.812997226	10	Medium
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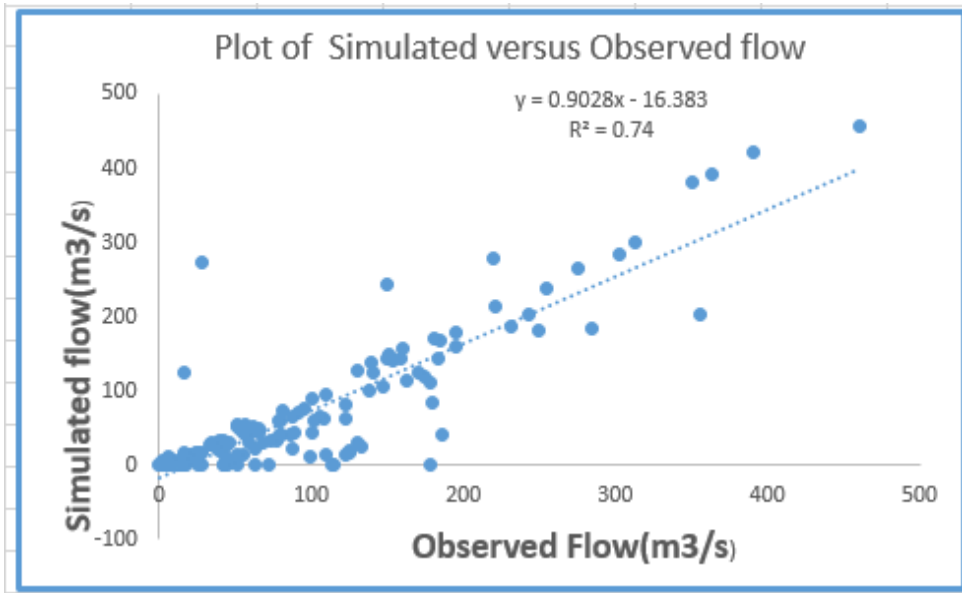


Figure4. 1 Regression plot of Observed and Simulated flow for Calibration.

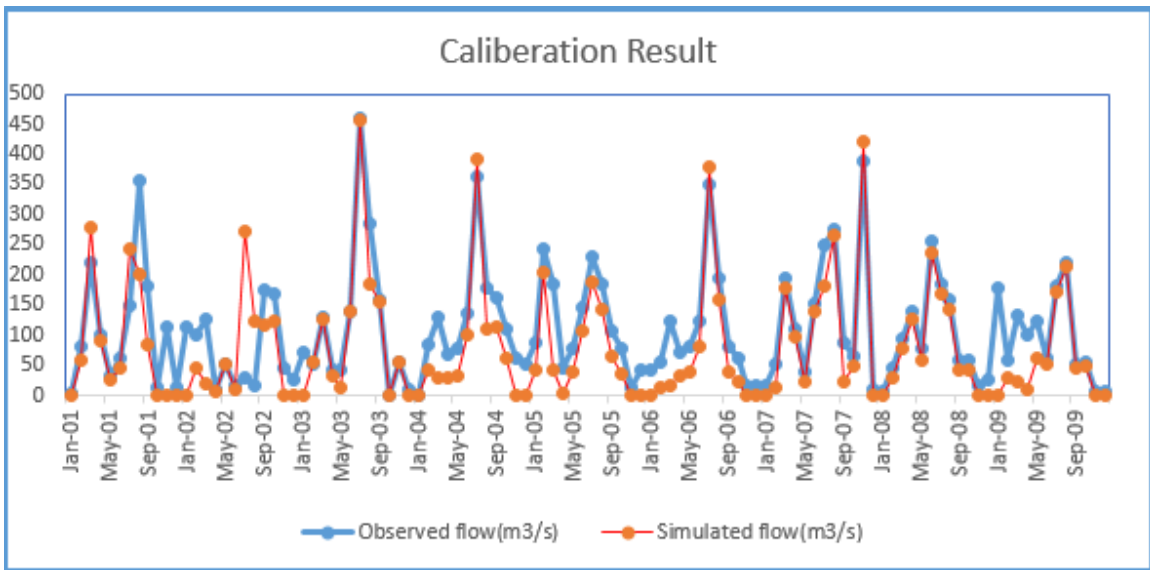


Figure4. 2 Monthly observed and simulated flow hydrograph during calibration

Validation

Validation is described as the procedure of showing that a give model is capable of making sufficiently precise simulations with an independent data set.(Arnold et al, 2012). It is used to test the calibrated parameters with an independent set of data without further

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changes to the parameters. In this study the validation was performed to compare the model outputs with an independent data set without making further change to parameters obtained during the calibration process. The measured data of average monthly flow from 2010-2012 at Harekelo Gauging station was used for model validation.

It involves model run with unchanged flow parameters which were adjusted during calibration process. During the validation period from January 1, 2010 to December 31, 2012 the performance of the model was evaluated for the Harekelo gauging station and at outlet of watershed. The uncertainty of the calibrated and validated model in SUFI-2, 95PPUs, is the combination of uncertainties in the input data, model structure and model parameters. The performance value of the model during Validation good having R^2 of (0.76) and E_{NS} of 0.71 at Harekelo gauging station at outlet of watershed.

Using monthly observed and simulated result hydrograph was developed for calibration period of 2001 to 2009 and validation period of 2010 to 2012 as shown in figure 4.3 and figure 4.4

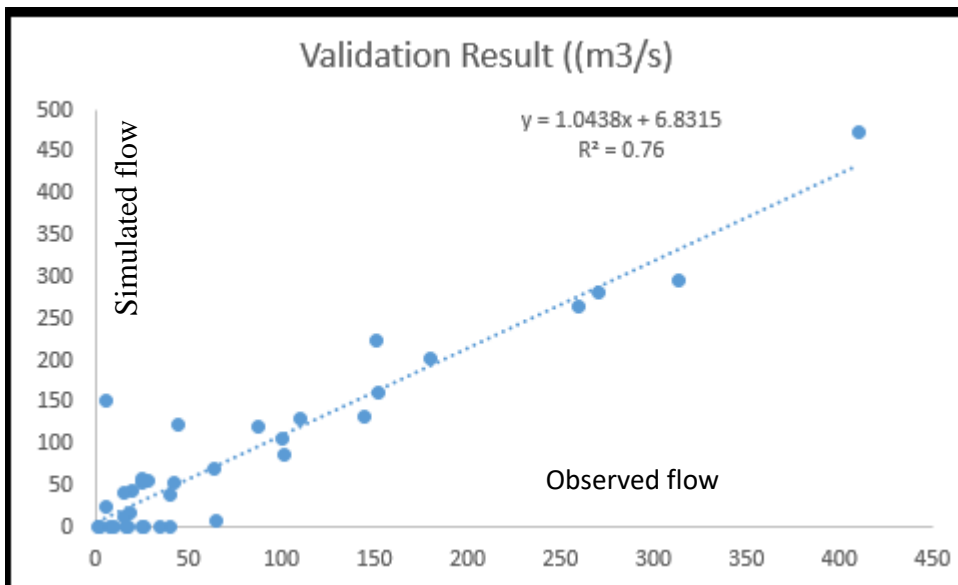


Figure4. 3 Regression plot of Observed and Simulated flow for Validation

Prediction of Sediment Yield to Lake Ziway Reservoir Using ARC-SWAT Software.

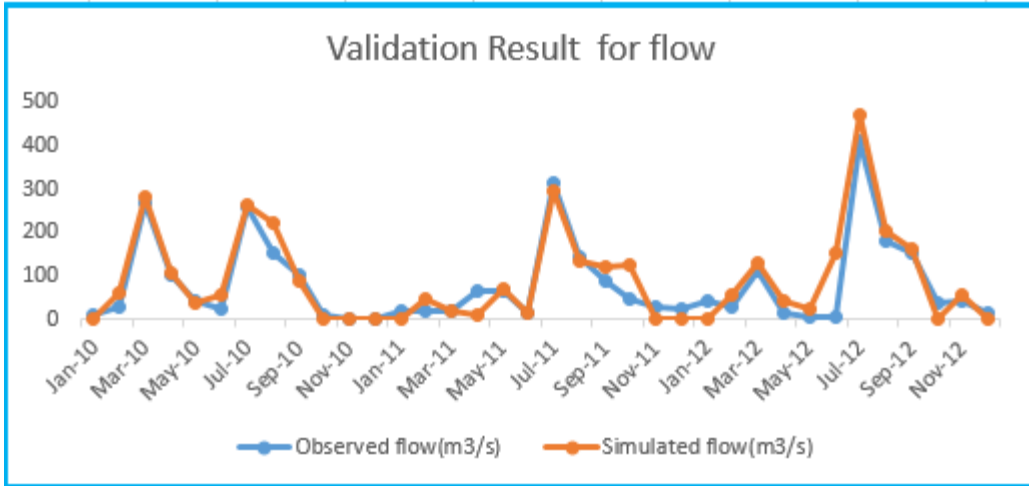


Figure4. 4 Monthly observed and simulated flow hydrograph during calibration

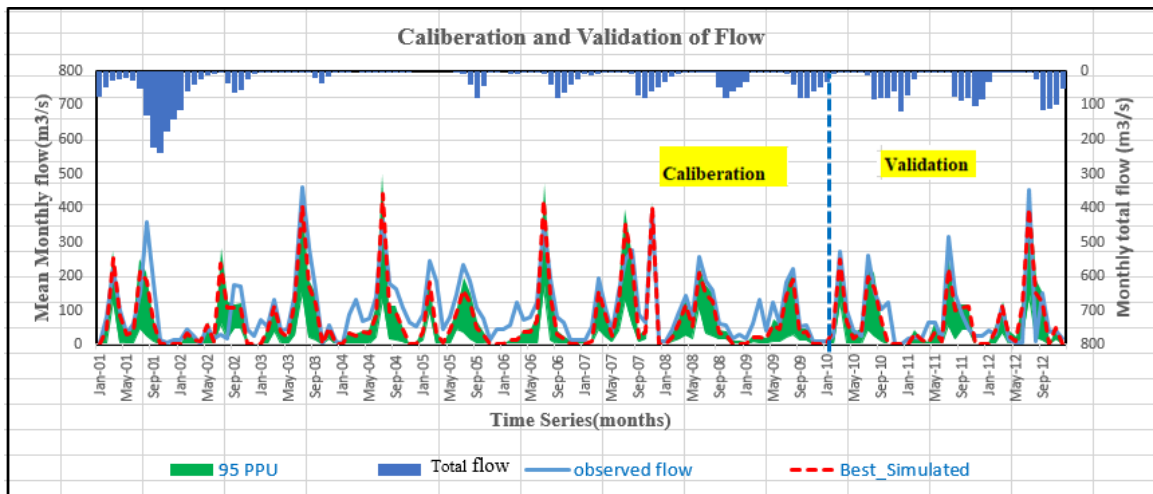


Figure4. 5 Monthly observed and simulated flow hydrograph during calibration and validation period (2001-2012).

4.4. Sediment Yield Simulation

4.4.1 Sensitivity Analysis

Like flow, sensitivity analysis was applied to identify the sediment sensitive parameters that influence the modeling of sediment yield. Sensitivity analysis carried out for two years warm-up period 2001 to 2003 and seven years calibration period 2003 to 2009. During sensitivity analysis of sediment yield fifteen sediment parameters were checked using SUFI-2 algorithm in SWAT-CUP. Based on the results obtained from sensitivity analysis, ranks of sediment parameters assigned depending on p-value and t-stat (Table

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4.3). From fifteen parameters, nine parameters from high to medium sensitive were identified for sediment calibration process.as shown below.

4.4.2 Sediment yield Calibration and Validation

Once the sediment sensitive parameters were identified during sensitivity analysis, calibration process took place. Similar to flow, the model was calibrated for sediment yield from 2001 to 2009.Sediment yield calibration and parameters adjustment continued iteratively until simulated and observed sediment yield fitted.

Table 4. 3 Selected Sediment calibration parameters in the watershed.

Parameter Name	t-Stat	P-Value	Rank	Sensitivity
15:V__HRU_SLP.hru	-12.377218899	0.000000000	1	High
5:V__USLE_K(..).sol	-11.262678712	0.000000000	2	High
1:V__USLE_P.mgt	-11.174101476	0.000000000	3	High
2:V__ALPHA_BF.gw	-2.680567953	0.007557282	4	High
11:R__CN2.mgt	-2.187393662	0.029109571	5	midium
10:R__SPEXP.bsn	-2.059175853	0.039920210	6	midium
3:V__GWQMN.gw	1.749951807	0.080651810	7	midium
12:R__SPCON.bsn	-1.612862931	0.107314503	8	midium
14:V__GW_DELAY.gw	-1.152799946	0.249464140	9	midium
13:R__GW_REVAP.gw	1.029855475	0.303504180	10	low
8:R__CH_ERODMO(..).rte	0.831247710	0.406173434	11	low
4:R__CANMX.hru	0.808475289	0.419146241	12	low
9:V__USLE_C{..}.plant.dat	-0.698319280	0.485255509	13	low
6:V__CH_COV1.rte	0.352625086	0.724496755	14	low
7:R__CH_COV2.rte	-0.210294984	0.833510798	15	low

Sediment yield Validation conducted with independent sediment measured data for the periods 2010 to 2012 without further adjustment of calibration fitted parameters. The model efficiency of predicting the sediment yield and uncertainty of its prediction for calibration and validation was checked through model performance evaluation criteria and model uncertainty measures. According to model performance evaluation criteria the sediment simulation result for calibration and validation at Harekelo gauging station showed a very good performance with R^2 of 0.8, ENS of 0.76 for Calibration and R^2 of 0.84, ENS of 0.71 for Validation.

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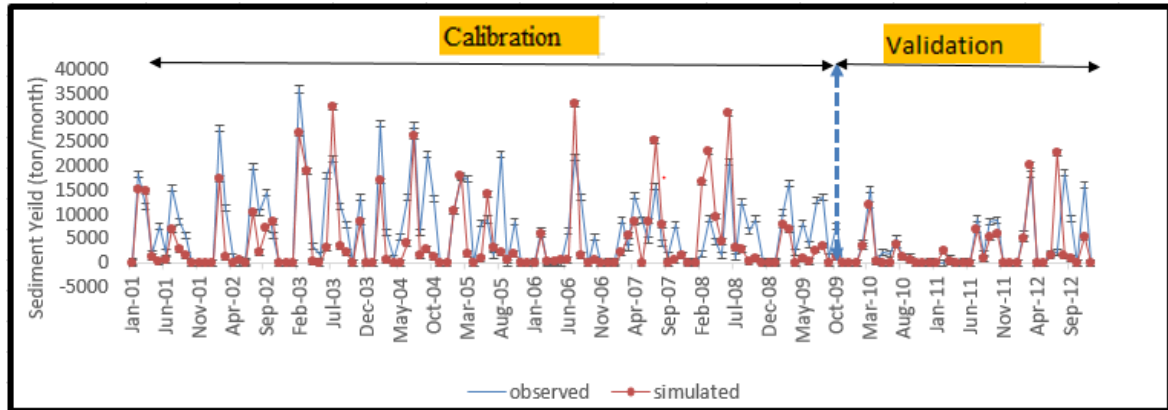


Figure 4. 6 Simulation of sediment for calibration and Validation (2001-2012)

Average Annual sediment yield from Lake Ziway watershed after calibration and validation Harekelo gauging station was 2.69 ton/ha/year for period of 2001 to 2012.

Therefore, USLE soil erodibility factor (USLE_K.sol) is the most sensitive parameter next to the slope of HRU's in the Basin (HRU_SLP.hru), these parameters have direct impact on the value of sediment yield in the Watershed.

4.5 Spatial variability of Sediment Yield in the watershed

Spatial variability of sediment yield in the watershed of each sub basins due to the factors which affecting the sediment yield variability like land use/cover, soil type soil erodibility, rainfall distribution, topography and management practices.

According to Fikerte Seyum(Jimma university, January, 2019) The Soil Erosion or sedimentation level in basin were classified as low (0-6 ton/ha/yr) , moderate (6-12 ton/ha/yr) high (12-18 ton/ha/yr) and very high (>18 ton/ha/yr). While According to Setegn et al (2008), the hotspot areas were identified based on the values of sediment yield in tons/ ha and classified as Very low (0-9), low (9-17), moderate (17-30) and sever (30-65). The Sub- basins which are supplying high amount of sediment to the river system(Sub- basin 4,Sub- basin 5, Sub- basin 1) have land use , soil type and slope nature that facilitate erosion of the soil by different agents. Here in this case Fikerte's classification have been used.

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Thus, the sediment yield at each sub basin was not uniform as shown below in table 4.6 To get average annual sediment yield spatially with sub basins level, the SWAT model was run annually (1987-2017) for thirty one years. Spatial variability of sediment yield for the Lake –ziway Watershed was identified from the simulated annual sediment yield and the result shows the ranges was between 0.19 to 6.74 tons/ha/yr with average of 2.69 ton/ha/yr for the sub-basins. The average annual sediment yields of each sub basins are listed in table below. The Sub basin 4, 5 and 1 are the three most erodible sub-basins respectively, while Sub basin 10, 2 and 3 are less erodible Catchment.

Table 4. 4 Mean Annual sediment yield of each sub –basin in Lake-Ziway Watershed

Sub_Basin No	SYD(ton/ha/yr)	Sed_class
sub_1	4.21	low
sub_2	0.55	low
sub_3	0.77	low
sub_4	6.74	moderate
sub_5	6.23	moderate
sub_6	2.15	low
sub_7	1.79	low
sub_8	1.83	low
sub_9	1.70	low
sub_10	0.19	low
sub_11	1.52	low

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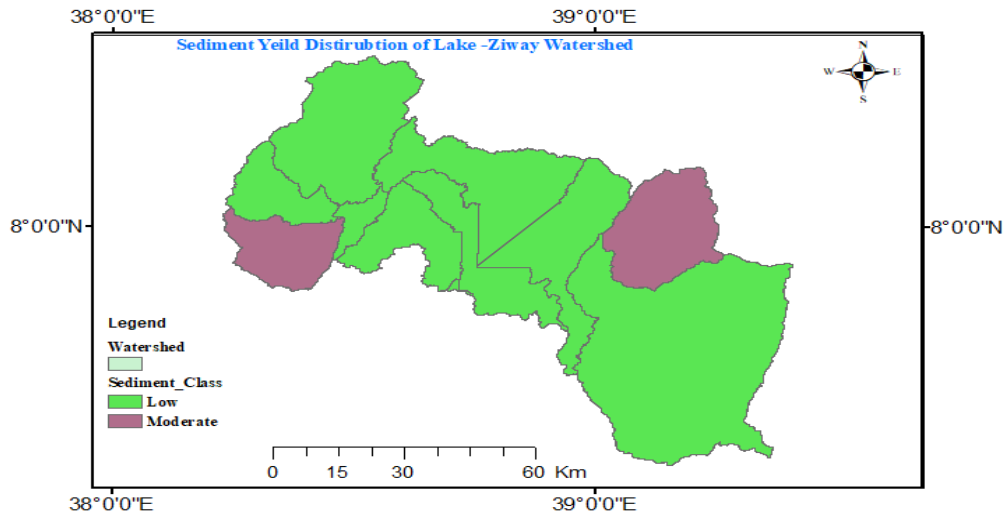


Figure 4. 7 Spatial variability of Sediment yield for Lake Ziway watershed.

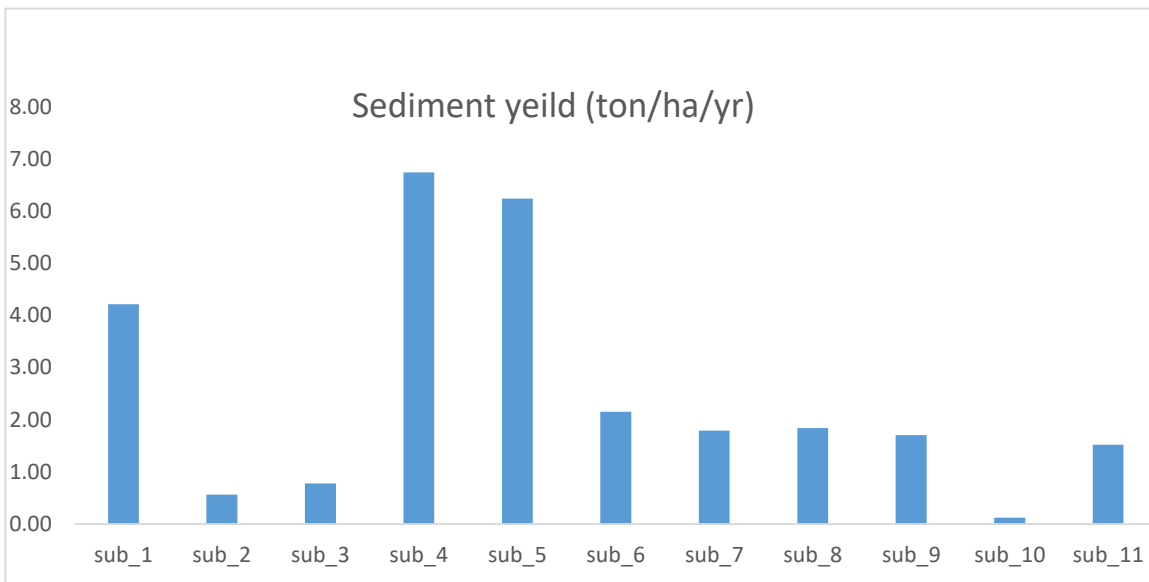


Figure 4.8 Sediment yield variability in Sub-Basins

All the selected catchments were characterized by a single land use class (agriculture) and one dominant soil type of Luvisols. In addition, the research employing catchment prioritization indicates that in low land areas with the same land use and soil type, the soil loss is low. This indicates that the variation of sediment yield is more sensitive to terrain slopes due to poor land use practices on steep slope areas.

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Based on the result obtained above, three management scenarios was developed and simulated in SWAT to identify the best management scenario among all.

Baseline scenario (scenario 0): The existing condition of the watershed is considered. This scenario used as reference for comparisons of the effectiveness of the developed sediment reduction scenarios. In this simulation, the calibrated values of SWAT model were used without changing any model parameter.

Table 4. 5 Scenario description and SWAT parameters used to represent Management

Soil Conservation types	Field Name/Parameter	Field type	Definition
Terracing	TERR_P	Float	USLE practice factor adjusted for terraces
	TERR_CN	Float	Initial SCS curve number II value
	TERR_SL	Float	Average slope length (m)
Grassed-Waterway	GWATI	Float	Flag for the simulation of grass waterways
	GWATN	Float	Manning's N value for overland flow
	GWATL	Float	Length of grassed waterway (km)
	GWATW	Float	Average width of grassed waterway (m)
	GWATD	Float	Depth of grassed waterway channel from top of bank to bottom (m)
	GWATS	Float	Average slope of grassed waterway channel (m)
	GWATSPCON	Float	Linear parameter for calculating sediment in Grassed waterways (default)
Filter Strips	VFSI	Float	Flag for the simulation of filter strips
	VFSRATIO	Float	Ratio of field area to filter strip area (ha ² / ha ²)
	VFSCON	Float	Fraction of the HRU which drains to the most concentrated ten percent of the filters strip area (ha ² / ha ²)
	VFSCH	Float	Fraction of the flow within the most concentrated ten percent of the filter strip which is fully channelized (dimensionless)

practices

Prediction of Sediment Yield to Lake Ziway Reservoir Using ARC-SWAT Software.

Scenario 1 (Terracing): This practices helps to reduce the overland flow, Sheet erosion and Slope length. Appropriate parameters are shown above.

Soil Conservation types	Field Name/Parameter	Existing Values	Simulated Values	Selected Sub basins
Terracing	TERR_P	0.5	1	Sub Basin 1,4 and 5,6 with slope >20% Containing AGRR,FRST,FRSE With soil types CHLUVISOLS EUCAMBISOLS MOANDOSOLS
	TERR_CN	60	82	
	TERR_SL	20	45	

Simulation of the above parameters Using Arc- Swat minimizes the Average sediment yeild from 2.69ton/ha/year to 0.76 ton/ha/yr which accounts 72% of reduction . this scenario again minmizes the maximum up land sediment from 48.82ton/ha/yr to 13.71 ton/ha/yr.

Scenario 2(Filter strips): This management practices were placed on all agricultural HRUs that are combination of croplands, soils and all slope classes. The effect of the trips is that to reduce run off and trap sediment in a given plot (Bracmort et al., 2006).

Soil Conservation types	Field Name/Parameter	Existing Values	Simulated Values	Selected Sub basins	Simulat ion of the above parame ters Using
Filter Strips	VFSI	0	0	All Except sub basin 2,10 and 3 with slope >10% for all soil types.	
	VFSRATIO	10	20		
	VFSCON	0.5	2		
	VFSCH	90	96		

Arc- Swat minimizes the Average sediment yeild from 2.69ton/ha/year to 1.56 ton/ha/yr

Prediction of Sediment Yield to Lake Ziway Reservoir Using ARC-SWAT Software.

which accounts 42% of reduction . this scenario again minmizes the maximum up land sediment from 48.82ton/ha/yr to 28.31ton/ha/yr.

Scenario 3 (Grassed Waterways): This practice reduces sediment yield by increasing sediment trapping efficiency and flow velocity.

Soil Conservation types	Field Name/Parameter	Existing Values	Simulated Values	Selected Sub basins
Grassed-Waterway	GWATI	0	0	All Except sub basin 2,10 and 3 with slope >10% for all soil types.
	GWATN	0.1	0.3	
	GWATL	1000	3000	
	GWATW	10	20	
	GWATD	1	1.5	
	GWATS	0.005	0.025	
	GWATSPCON	0.005	0.025	

Simulation of the above parameters Using Arc- Swat minimizes the Average sediment yeild from 2.69ton/ha/year to 1.12 ton/ha/yr which accounts 58% of reduction . this scenario again minmizes the maximum up land sediment from 48.82ton/ha/yr to 20.5ton/ha/yr.

Table 4. 6 Summary table of Scenarios

Sub_ Basin	Number of HRUs contained.	SYD(ton/ha/yr)	Sediment values due to terracing(ton/ha/yr)	Sediment values due to grassed water way(ton/ha/yr)	Sediment values due to filter strips(ton/ha/yr)
1	31	4.21	1.1788	1.7682	2.4418
2	2	0.55	0.154	0.231	0.319
3	7	0.77	0.2156	0.3234	0.4466
4	16	6.74	1.8872	2.8308	3.9092
5	10	6.23	1.7444	2.6166	3.6134
6	9	2.15	0.602	0.903	1.247
7	10	1.79	0.5012	0.7518	1.0382

Prediction of Sediment Yield to Lake Ziway Reservoir Using ARC-SWAT Software.

8	6	1.83	0.5124	0.7686	1.0614
9	18	1.70	0.476	0.714	0.986
10	4	0.19	0.0532	0.0798	0.1102
11	3	1.52	0.4256	0.6384	0.8816

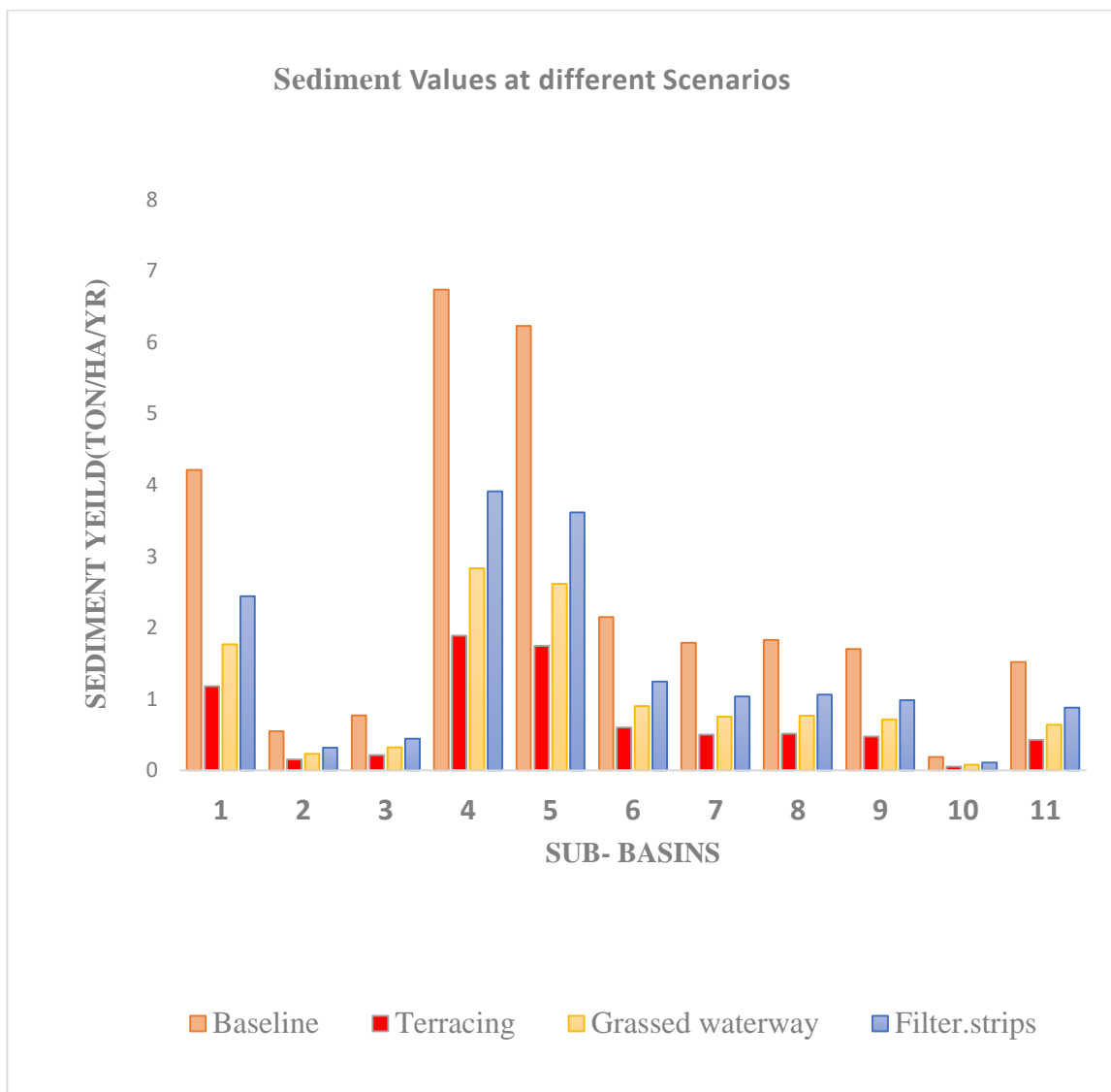


Figure 4.9 Different Scenarios reduces differently.

Prediction of Sediment Yield to Lake Ziway Reservoir Using ARC-SWAT Software.

Hence, this result can be used as a guideline for decision-makers to apply a suitable method to reduce the erosion load, especially from high erosion rate areas. On selected hotspot erosion areas, the required treatments may include practicing strip planting, terracing, or contour farming to reduce the effect of slope on surface runoff flow velocity and sediment transport capacity.

4.6 Sediment Yield Reduction Methods

Basically, there are many Sediment reduction strategies in different watersheds. A vegetative screen at the head of a reservoir, whether artificial or natural, serves to reduce the velocity of incoming flow and to cause sediment deposition. The vegetation does intercept the inflowing water, lowering the water supply to the reservoir by as much as 10%. Set up of buffer strips around lake –Ziway watershed to prevent sediments generated by area erosion and small stream erosion from reaching the reservoir directly and prevent the local inhabitants and grazing livestock from reaching the immediate vicinity of the reservoirs.

The intent of watershed management and soil conservation measures is to substantially reduce erosion and thereby decrease the sediment input to the stream system. The distribution of erosion over the watershed is investigated, and the areas contributing excessive sediment to the streams draining into the reservoir are demarcated. Conservation measures applied to these areas result in a significant reduction in sediment input to the reservoir. These measures include practices such as contour farming and terracing; strip cropping, crop rotation, grassed drainage ways, gully erosion control, and stabilization of critical areas by their return to grasslands or forests. Conservation measures take years to implement.

Prediction of Sediment Yield to Lake Ziway Reservoir Using ARC-SWAT Software.

5. CONCLUSION AND RECOMMENDATION

5.1. Conclusion

Soil erosion reduce the fertility and the productivity of agricultural land in the watershed and effects sedimentation problem at the outlet of watershed. In this study, annual average sediment yield estimation, spatial variability and identification of sediment prone areas, sediment reduction scenarios and comparison of scenarios result were carried out using SWAT model.

Based on SWAT model watershed delineation at Lake Ziway watershed the catchment area was delineated to be 7193Km². Overlaying land use, soil and slope were performed to generate HRUs. Climatic data from January 1987 - December 2017 were inputs during SWAT model simulation. The Calibration and Validation carried out from January 2001 - December 2009 and January 2010 - December 2012 respectively on monthly basis of stream flow and sediment data using automatic calibration with sequential uncertainty fitting (SUFI-2) in SWAT- CUP.

Saturated hydraulic conductivity (SOL_K.sol),,SCS runoff curve number (CN2.mgt), (ALPHA_BF.gw) and Available water capacity of the soil layer (SOL_AWC.sol), (SOL_BD..sol) Surface runoff lag time (SURLAG.bsn), are considered to more highly sensitive while the remaining parameters GWQMN.gw, HRU slope(HRU_SLP.hru), Channel conductivity(CH_K2.rte),EPCO.hru and ESCO.hru are medium sensitive parameters. The last three parameters were taken to be less sensitive based on t-Stat and P-Value for Calibration and validation of Stream flow.

During sediment calibration, slope of hydrological response unit (HRU_SLP.hru) ,USLE soil erodibility factor (USLE_K.sol), USLE soil practice factor (USLE_P.mgt) and ALPHA_BF.gw were considered as highly sensitive sediment parameters played significant role in the overall simulation process for sediment yield.

Prediction of Sediment Yield to Lake Ziway Reservoir Using ARC-SWAT Software.

Model performance efficiency was checked by coefficient of determination (R^2), Nash-Sutcliffe model efficiency (ENS), vary between 0.79 - 0.85, 0.72 - 0.78, respectively during calibration and validation period for both discharge and sediment yield. These the mentioned results depicted that model was well reasonably simulated the discharge and sediment yield from the watershed. The simulated annual average sediment yield at Lake Ziway Watershed was 2.69 ton/ha/ yr and the gross sediment entering to the lake was estimated to be 1.04million ton/yr with 38.5% of deposition rate. The spatial variability of the annual sediment yield rate distribution showed the sediment yield rate of the watershed ranges from 0.19 to 6.74ton/ha/yr. The majorities of prone areas are relatively steeper in slope and dominantly covered with intensively and moderately cultivated land.

The developed sediment yield reduction scenarios result showed that average annual sediment yield were reduced at entire watershed level after the mageneent practices had been applied. Taking the existing condition of the watershed as a baseline scenario for reference purpose, three scenarios were built. The first scenario, terracing reduces Average sediment yield by 72% from 2.69 Mton/ha to 0.76Mton/ha. While filter strips reduces Average sediment yield by 42% from 2.69 Mton/ha to 1.56Mton/ha and grassed water ways by 58% from 2.69 to 1.12 Mton/ha so that terracing is taken to be the best management practice among the three Scenarios. Sub basin 4and 5 were identified to be the hot spot areas in the watershed.

Prediction of Sediment Yield to Lake Ziway Reservoir Using ARC-SWAT Software.

5.2 Recommendation

For this study, input data (hydro-meteorological data) collected from the concerned offices and authorities were used to simulate the SWAT model in the study watershed. In order to improve the model performance, it is highly recommended that the hydrometric and meteorological gauging stations should be improved both in quality and quantity. It was better if there was primary data than secondary data.

The sediment gauging stations in this watershed are recorded small number of sediment data. Hence, it is better to increase number of recorded time and number of hydrological stations to get better result. The study can be further extended to similar neighboring sub-basins and watershed, it could be also a means to support and fill the gaps for researchers who want to study next in the basin level.

In this study, the amount of sediment yield was estimated with identification of sediment prone areas and management practices developed for those affected sub basins in current watershed condition. It is recommended that for the future study, estimating the amount of sediment yield under climate change.

In order to improve the sediment reduction in the Lake Ziway watershed additional management practices should be established from SWAT model management operation or other Soil and water conservation measures should be introduced.

Prediction of Sediment Yield to Lake Ziway Reservoir Using ARC-SWAT Software.

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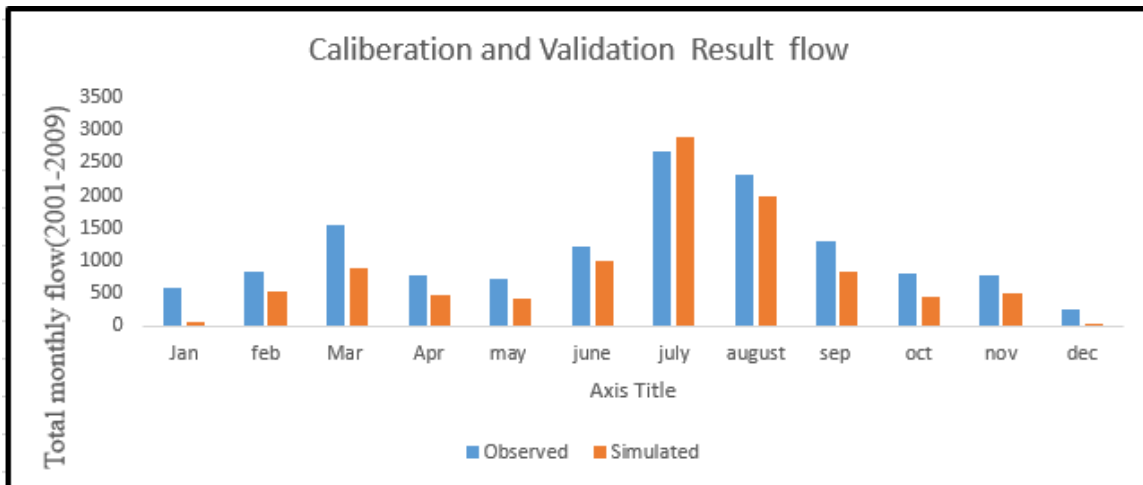
Prediction of Sediment Yield to Lake Ziway Reservoir Using ARC-SWAT Software.

7. APPENDIXES

Appendix A: mean monthly precipitation (mm) values of selected stations from (1987-2017)

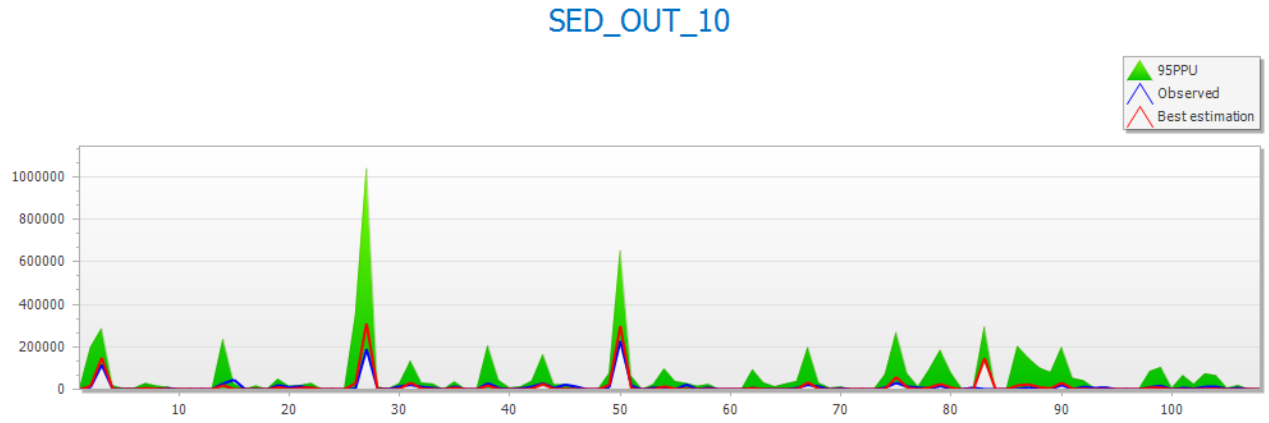
Month	Adami	Butajira	Assella	Bui	Eteya	Meki	Sagure	Meararo	Ziway
January	14.432	16.45754	16.45754	18.64084	15.87083	6.372	11.69444	24.59565	14.69701
Februray	30.52103	38.52181	38.52181	49.61118	22.87623	33.07786	41.55664	40.08763	35.26811
March	54.25602	99.25232	99.25232	91.05434	66.70061	65.83022	61.3613	65.75891	53.1722
April	75.74449	119.8074	96.05	95.40045	76.10472	68.47193	82.5545	103.2706	71.45583
May	83.83133	108.4435	108.4435	97.7263	101.9105	62.99993	79.34549	73.24423	83.69144
June	91.90367	116.4364	116.4364	100.03	100.9307	72.15809	97.5416	75.07667	83.76162
July	192.3748	170.0598	170.0598	205.9119	216.4141	174.5341	133.4114	154.3493	166.3738
August	144.2052	170.2321	170.2321	194.8406	174.0667	141.1568	134.6556	184.589	116.1234
Septmebr	92.90178	135.3461	135.3461	106.535	142.3787	74.84938	79.61577	102.3466	81.73766
October	34.27302	44.04251	44.04251	28.51368	30.54027	19.10746	28.63353	43.63823	28.11984
Novemebr	1.962593	12.10032	12.10032	7.484628	13.62243	5.351364	6.445988	15.36606	3.728952
December	10.04797	17.66659	17.66659	10.48497	5.269479	6.361053	8.797625	19.02833	7.428955

Appendix B: Calibration and validation of total monthly flow (2001-2012)

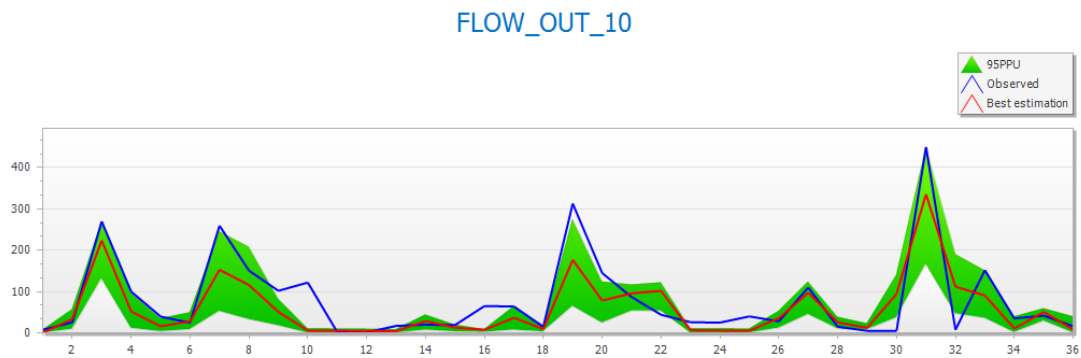


Appendix C: Simulation result for Sediment on using SUFI-2

Prediction of Sediment Yield to Lake Ziway Reservoir Using ARC-SWAT Software.

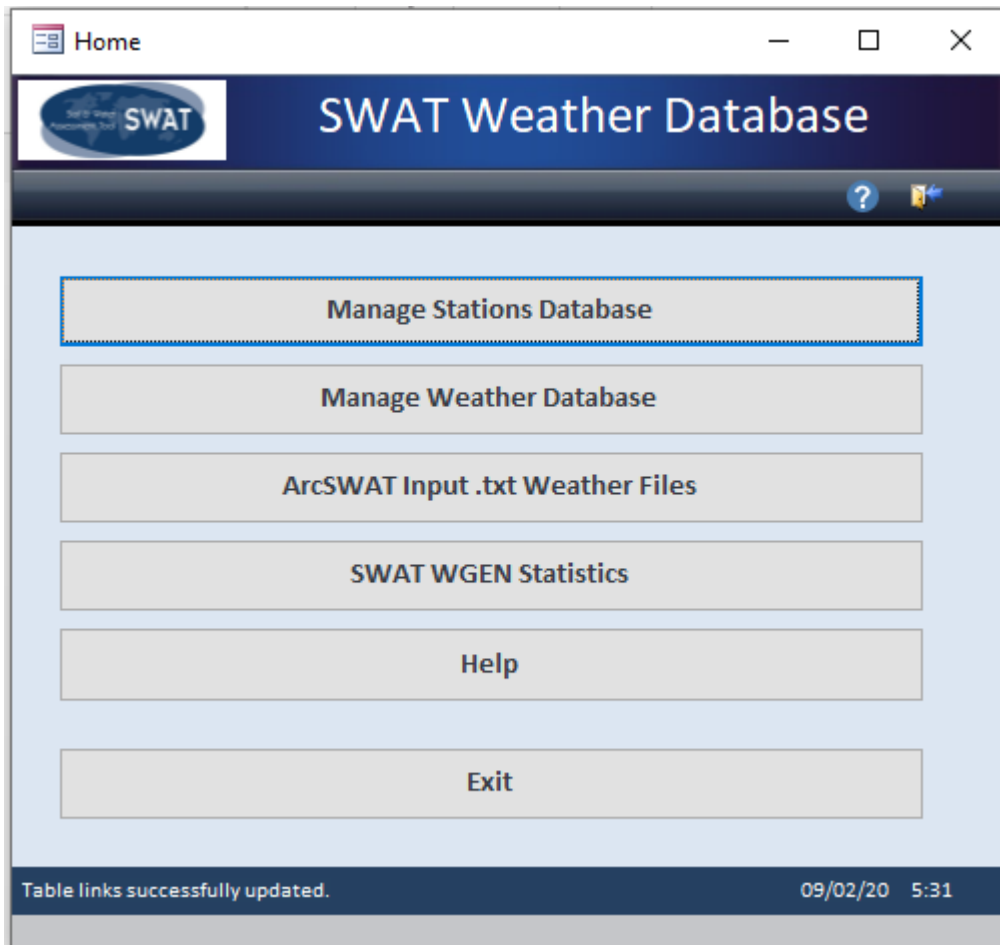


Appendix D: Simulation result for stream flow on using SUFI-2



Prediction of Sediment Yield to Lake Ziway Reservoir Using ARC-SWAT Software.

Appendix E: Set up for weather data base generator.



Appendix F: Watershed report after delineation

Prediction of Sediment Yield to Lake Ziway Reservoir Using ARC-SWAT Software.

TopoRep.txt - Notepad

File Edit Format View Help

Elevation report for the watershed 01/01/01 7:21:34 PM 08/11/20 12:00:00 AM

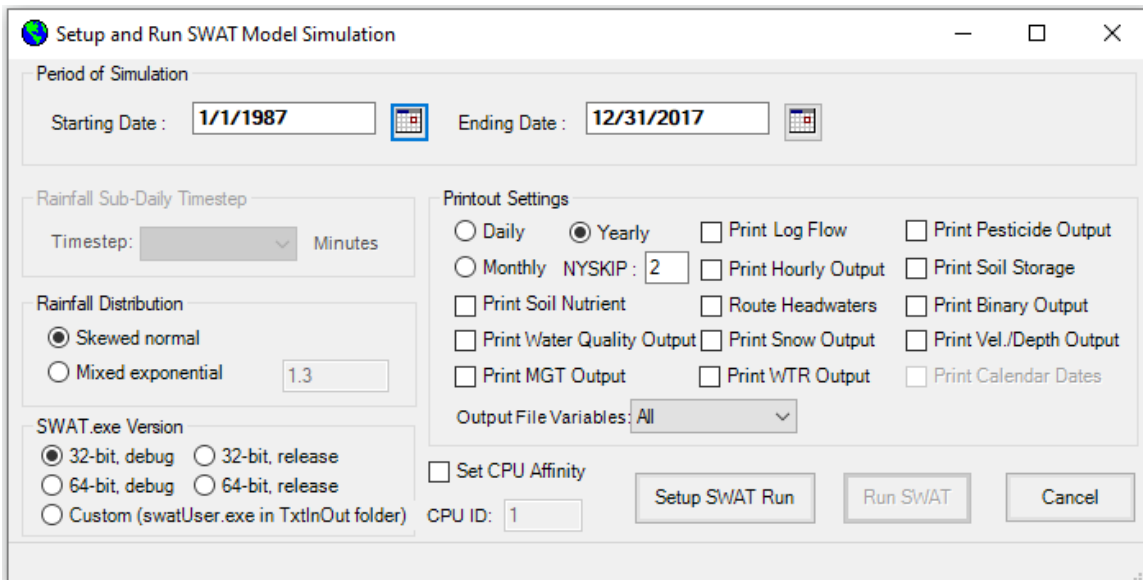
Statistics:: All elevations reported in meters

```

Min.   Elevation: 1635
Max.   Elevation: 4200
Mean.  Elevation: 2246.60728676784
Std.   Deviation: 543.504698521582
    
```

Elevation	% Area Below Elevation	% Area Watershed
1635	8.22	8.22
1636	8.52	.31
1637	8.78	.25
1638	8.98	.2
1639	9.15	.17
1640	9.3	.15
1641	9.43	.13
1642	9.55	.12
1643	9.67	.11
1644	9.77	.1
1645	9.87	.1
1646	9.97	.1
1647	10.09	.12
1648	10.2	.11
1649	10.32	.12
1650	10.47	.15
1651	10.6	.14
1652	10.77	.16

Appendix G: Set up to run SWAT



Appendix H: Format of Hydrologic response Units report

Prediction of Sediment Yield to Lake Ziway Reservoir Using ARC-SWAT Software.

Detailed LANDUSE/SOIL/SLOPE distribution SWAT model class Date: 08/11/20 12:00:00 AM Time: 20:59:59.6643117

	Area [ha]	Area[acres]	
Watershed	719306.6194	1777442.6218	
Number of Subbasins: 11			

	Area [ha]	Area[acres]	%Wat.Area
LANDUSE:			
Forest-Mixed --> FRST	68837.1317	170099.9943	9.57
Forest-Evergreen --> FRSE	22489.2817	55572.1395	3.13
Forest-Deciduous --> FRSD	32554.7541	80444.4251	4.53
Agricultural Land-Row Crops --> AGRR	461975.5140	1141564.5939	64.23
Pasture --> PAST	57512.9423	142117.3562	8.00
Barren --> BARR	20941.5778	51747.6857	2.91
Wetlands-Non-Forested --> WETN	6750.0136	16679.6211	0.94
Water --> WATR	42788.6662	105732.9336	5.95
Residential-High Density --> URHD	5456.7380	13483.8723	0.76

SOILS:			
CHLUVISOLS	81325.2510	200958.7615	11.31
EUCAMBISOLS	84625.8341	209114.6675	11.76
EUFLUVISOLS	9656.0289	23860.5301	1.34
EUVERTISOLS	210829.7820	520970.9329	29.31
FBHISTOSOLS	8856.1898	21884.0879	1.23
HPLUVISOLS	56623.7586	139920.1388	7.87
HUNITISOLS	3611.8836	8925.1450	0.50
LTLEPTOSOLS	29397.4853	72642.6560	4.09
LUPHAEZEMS	59676.3536	147463.2535	8.30
MOANDOSOLS	58368.6558	144231.8669	8.11
VTANDOSOLS	22522.0263	55653.0530	3.13
VTCAMBISOLS	51579.2761	127454.9702	7.17
WATER	42234.0942	104362.5585	5.87

Appendix I: Some Section from Final HRU Report.

SWAT model simulation Date: 08/11/20 12:00:00 AM Time: 00:00:00
 MULTIPLE HRUs LandUse/Soil/Slope OPTION THRESHOLDS : 10 / 10 / 15 [%]
 Number of HRUs: 116
 Number of Subbasins: 21

	Area [ha]	Area[acres]	
Watershed	719306.6194	1777442.6218	

	Area [ha]	Area[acres]	%Wat.Area
LANDUSE:			
Forest-Mixed --> FRST	52042.6480	128599.9854	7.24
Agricultural Land-Row Crops --> AGRR	554093.0356	1369191.5956	77.03
Pasture --> PAST	44648.5707	110328.8506	6.21
Water --> WATR	49756.7043	122951.3042	6.92
Forest-Deciduous --> FRSD	18765.6608	46370.8860	2.61

SOILS:			
CHLUVISOLS	41859.8508	103437.7843	5.82
EUVERTISOLS	253794.2697	627138.3301	35.28
LTLEPTOSOLS	25196.8454	62262.6649	3.50
EUCAMBISOLS	89020.6802	219974.5517	12.38
VTANDOSOLS	16518.8922	40819.0085	2.30
LUPHAEZEMS	65756.9037	162488.5969	9.14
FBHISTOSOLS	5531.5405	13668.7131	0.77
HPLUVISOLS	68651.2141	169640.5826	9.54
MOANDOSOLS	45566.3719	112596.7834	6.33
EUFLUVISOLS	5726.7502	14151.0861	0.80
VTCAMBISOLS	51926.5964	128313.2159	7.22
WATER	49756.7043	122951.3042	6.92

SLOPE:			
40-9999	16966.8729	41925.9913	2.36

Prediction of Sediment Yield to Lake Ziway Reservoir Using ARC-SWAT Software.

Appendix J: Samples to show Bi -modal and Uni- modal rainfall distributions.

